PYG 345/4.10/7
No 77

Information Circular 77

Combines IC 18-35, 37-42, 44-4

GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAPS OF SOUTHEASTERN PENNSYLVANIA

Arthur A. Socolow

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURC
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

LIBRARY

Digitized by the Internet Archive
in 2016 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/geologicinterpre00penn

Information Circulars 18-35, 37-42, 44-46

GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAPS OF SOUTHEASTERN PENNSYLVANIA

by Arthur A. Socolow

THE

PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES
HARRISBURG

First Printing of IC 18-35: 1959
First Printing of IC 37, 38, 39, 40, 42: 1960
First Printing of IC 41, 44, 45, 46: 1961
Second Printing, 1974

Quotations from this book may be published if credit is given
to the Pennsylvania Geological Survey

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PURCHASED FROM
STATE BOOK STORE, P. O. BOX 1365
HARRISBURG, PENNSYLVANIA 17125

PREFACE

Southeastern Pennsylvania is an area of extremely varied and complex geology with a long history of mineral production. The list of mineral commodities which this area has yielded at various times is considerable, but iron ore stands out as the most prominent. Scores of iron mines and furnaces have operated in this area in the past 200 years. With a record of production dating back to pre-Revolutionary War years, the mine at Cornwall was America's oldest continuously operating iron mine in the United States. The development of the large and magnificent Grace Mine at Morgantown is living testimony to the fact that Pennsylvania's metallic mining record is not simply a story of the past. Through modern methods of exploration and research, new mineral resources remain to be found.

The Bureau of Topographic and Geologic Survey is pleased to have participated and cooperated with the U. S. Geological Survey in carrying out an aeromagnetic survey of southeastern Pennsylvania. This modern exploration technique is particularly well suited to the geologic conditions and to the potential mineral resources of the area; it is an extremely efficient method of acquiring geologic data for a large region. The results of the aeromagnetic survey are being published by the U. S. Geological Survey as a series of aeromagnetic contour maps.

We are pleased to present this publication as a service to the Commonwealth of Pennsylvania. It is hoped that this interpretation and discussion of the aeromagnetic maps will serve as a stimulus for further research and development.

ARTHUR A. SOCOLOW

CONTENTS

Page

Preface ... iii

General statement ... 1

Information Circular 18
Valley Forge quadrangle ... 4

Information Circular 19
Norristown quadrangle ... 5

Information Circular 20
Malvern quadrangle ... 6

Information Circular 21
West Chester quadrangle ... 7

Information Circular 22
Media quadrangle ... 8

Information Circular 23
East Greenville quadrangle ... 10

Information Circular 24
Milford Square quadrangle ... 13

Information Circular 25
Sassamansville quadrangle ... 15

Information Circular 26
Perkiomenville quadrangle ... 16

Information Circular 27
Phoenixville quadrangle ... 17

Information Circular 28
Allentown quadrangle ... 17

Information Circular 29
Quakertown quadrangle ... 21

Information Circular 30
Buckingham, Lambertville and Stockton quadrangles ... 23

Information Circular 31
Safe Harbor quadrangle ... 24

Page

Information Circular 32
Conestoga quadrangle 25

Information Circular 33
Quarryville quadrangle 27

Information Circular 34
Morgantown quadrangle 28

Information Circular 35
Elverson quadrangle 29

Information Circular 37
Pottstown quadrangle 31
Wagontown quadrangle 32
Downingtown quadrangle 33
Coatesville quadrangle 34
Unionville quadrangle 36
Honey Brook quadrangle 36
Parkesburg quadrangle 37

Information Circular 38
Temple quadrangle 38
Fleetwood quadrangle 39
Manatawny quadrangle 40
Reading quadrangle 45
Birdsboro quadrangle 47
Boyertown quadrangle 49

Information Circular 39
Easton quadrangle 53
Riegelsville quadrangle 54

Information Circular 40
Hatboro quadrangle 55
Langhorne quadrangle 56

Information Circular 41
Womelsdorf quadrangle 57
Sinking Spring quadrangle 58
Ephrata quadrangle 58
Terre Hill quadrangle 59
Leola quadrangle 59
New Holland quadrangle 59
Gap quadrangle 60

Page

Lebanon and Richland quadrangles 62
Manheim quadrangle 65
Lititz quadrangle 66
Columbia East quadrangle 66
Lancaster quadrangle 67

Information Circular 42
Collegeville quadrangle 67
Bedminster quadrangle 67
Lumberville quadrangle 68
Telford quadrangle 68
Doylestown quadrangle 68
Lansdale quadrangle 69
Ambler quadrangle 69

Information Circular 44
Alburtis quadrangle 70

Information Circular 45
Hummelstown quadrangle 71
Palmyra quadrangle 71
Bernville quadrangle 72

Information Circular 46
Regional setting 72
York and Red Lion quadrangles 75
Glen Rock quadrangle 77
Abbottstown and West York quadrangles 79
Hanover and Seven Valleys quadrangles 79

References 83

ILLUSTRATIONS

FIGURES

Figure 1. Index map to geophysical (GP) maps 3

Figure 2. Map showing positive magnetic anomalies and geology of the Cornwall area *follows* 62

Figure 3. Map showing geology of the York-Hanover district *follows* 74

Figure 4. Map showing preliminary geological observations at Strickhouser mine 82

GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAPS OF SOUTHEASTERN PENNSYLVANIA

by
Arthur A. Socolow

GENERAL STATEMENT

The magnetic contour maps being discussed in this series of publications are the result of a cooperative project of the United States Geological Survey and the Pennsylvania Geological Survey. About 10,000 square miles of southeastern Pennsylvania were covered in this survey, the results of which have been published by the U. S. Geological Survey as individual 7½-minute-quadrangle aeromagnetic maps.

These information circulars are intended as a preliminary explanation of the interrelation of distinctive magnetic features with geological conditions in each quadrangle. In many instances unusual magnetic patterns can be explained by geological features which have been mapped and studied in the past. It is hoped that the map viewer will not only be aided by such correlation of data, but that this publication may stimulate exploration and research in those areas where there is at present no known or satisfactory geological explanation for some of the magnetic features which appear on the magnetic contour map. Such exploration and research could directly or indirectly lead to discovery and development of new mineral deposits and would greatly further the basic knowledge of the geology of Pennsylvania.

The magnetic contour lines on the map are lines connecting points of equal magnetic intensity. The shape, position, and spacing of the magnetic lines are due to the combined effects of the earth itself, which is a huge magnet, and to the local variations in the magnetism of the rocks underlying any given area. If only the earth as a large, uniform body were responsible for the magnetic lines, they would be essentially straight and simple. It is the local geology, however, which imparts complexities to the patterns of the magnetic lines. Such complexities or variations from a simple pattern are called anomalies.

Local magnetic effects vary from place to place because the magnetic properties of the respective rocks are not alike or because differences in rock structure from place to place change the magnetism measured at the surface. Rocks which have different kinds or different relative amounts of minerals, particularly iron-bearing minerals, have unlike magnetic properties. In general, the more iron minerals present, the stronger the magnetic effect. The iron oxide mineral, magnetite, has a strong magnetic effect even when present in small quantities; when present in large amounts, magnetite is of economic interest as a possible iron ore.

If in a given area the rocks have been folded or faulted by internal earth forces, the resulting variation in position of the different rocks will be indicated by variation in magnetic readings from place to place. Thus, structural complexities as well as mineral variations may be revealed by the magnetic data. Of particular interest are those magnetic variations or anomalies which are circular or tend to enclose a given area; the implication in such cases is that there is a specific, localized causative factor more or less pinpointed by such a pattern.

The aeromagnetic survey of southeastern Pennsylvania was carried out with the use of an airborne magnetometer, an instrument towed by a plane. The plane covered the area by flying back and forth along straight, parallel flight lines spaced a quarter mile apart. An attempt was made to maintain an elevation of 500 feet above the ground in order to eliminate magnetic changes due solely to terrain changes. An airborne magnetic survey has the advantage of eliminating very minor magnetic features on the ground, thus permitting a better evaluation of larger and deeper magnetic phenomena. It should be borne in mind that the instruments which have measured the magnetic effects in these studies are very sensitive and capable of detecting small changes. Proper evaluation of these changes is necessary to distinguish those situations which offer possibilities for economic mineral development from those cases where the information yielded is of more academic interest.

The following index map shows the location of the quadrangles covered by U. S. Geological Survey aeromagnetic maps as part of their GP map series. Also listed are the corresponding interpretive Information Circulars published by the Pennsylvania Geological Survey in this report.

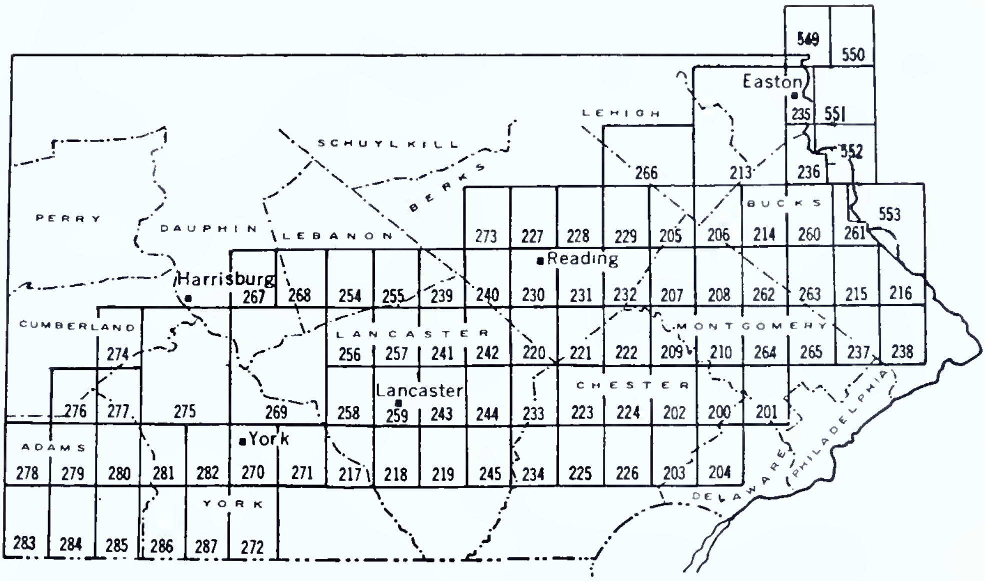

Figure 1. Index map to geophysical (GP) maps.

GP Map No.	Quadrangle Name	IC No.
200	VALLEY FORGE	18
201	NORRISTOWN	19
202	MALVERN	20
203	WEST CHESTER	21
204	MEDIA	22
205	EAST GREENVILLE	23
206	MILFORD SQUARE	24
207	SASSAMANSVILLE	25
208	PERKIOMENVILLE	26
209	PHOENIXVILLE	27
210	COLLEGEVILLE	42
213	ALLENTOWN	28
214	QUAKERTOWN	29
215	BUCKINGHAM	30
216	PARTS OF LAMBERTVILLE AND STOCKTON	30
217	SAFE HARBOR	31
218	CONESTOGA	32
219	QUARRYVILLE	33
220	MORGANTOWN	34
221	ELVERSON	35
222	POTTSTOWN	37
223	WAGONTOWN	37
224	DOWNINGTOWN	37
225	COATESVILLE	37
226	UNIONVILLE	37
227	TEMPLE UNIVERSITY	38
228	FLEETWOOD	38
229	MANATAWNY	38
230	READING	38
231	BIRDSBORO	38
232	BOYERTOWN	38
233	HONEY BROOK	37
234	PARKESBURG	37
235	EASTON	39
236	RIEGELSVILLE	39
237	HATBORO	40
238	LANGHORNE	40
239	WOMELSDORF	41
240	SINKING SPRING	41
241	EPHRATA	41
242	TERRE HILL	41
243	LEOLA	41
244	NEW HOLLAND	41
245	GAP	41
254	LEBANON	41
255	RICHLAND	41
256	MANHEIM	41
257	LITITZ	41
258	COLUMBIA EAST	41
259	LANCASTER	41
260	BEDMINSTER	42
261	LUMBERVILLE	42
262	TELFORD	42
263	DOYLESTOWN	42
264	LANSDALE	42
265	AMBLER	42
266	ALBURTIS	44
267	HUMMELSTOWN	45
268	PALMYRA	45
270	YORK	46
271	RED LION	46
272	GLEN ROCK AND PART OF NEW FREEDOM	46
273	BERNVILLE	45
274	MECHANICSBURG	*
275	NEW CUMBERLAND	*
276	MOUNT HOLLY SPRINGS	*
277	DILLSBURG	*
278	ARENDTSVILLE	*

(Continued)

Figure 1. *(Continued)*

GP Map No.	Quadrangle Name	IC No.
279	BIGLERVILLE	*
280	HAMPTON	*
281	ABBOTTSTOWN	46
282	WEST YORK	46
283	FAIRFIELD AND PART OF EMMITSBURG	*
284	GETTYSBURG AND PART OF TANEYTOWN	*
285	McSHERRYSTOWN AND PART OF LITTLESTOWN	*

* Not available.

GP Map No.	Quadrangle Name	IC No.
286	HANOVER AND PART OF MANCHESTER	46
287	SEVEN VALLEYS AND PART OF LINEBORO	46
549	BANGOR	*
550	BELVIDERE	*
551	BLOOMSBURY AND PART OF EASTON	*
552	FRENCHTOWN AND PART OF RIEGELSVILLE	*
553	PARTS OF LAMBERTVILLE, LUMBERVILLE AND STOCKTON	30

INFORMATION CIRCULAR 18. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, VALLEY FORGE QUADRANGLE

VALLEY FORGE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 200

The southern portion of the Valley Forge aeromagnetic contour map shows a number of linear anomalies which trend in an east-west direction and indicate various rock compositions and structures.

The northern half of the magnetic contour map shows only a few, widely spaced contour lines, indicating uniform magnetic properties of the rocks. The underlying rocks are Cambrian and Ordovician limestones and sandstones.

A distinctive, positive magnetic anomaly occurs in the southwestern portion of the map in Willistown and Easttown Townships. The anomaly has a width of about a half mile and a length on this quadrangle of about 4 miles; it actually continues westward onto the Malvern quadrangle. This anomaly corresponds exactly to a narrow belt of Wissahickon oligoclase-mica schist and serpentine. Along the same trend farther to the east at Wayne in Radnor Township, another linear positive magnetic anomaly lies directly over a continuation of the narrow belt of Wissahickon schist. Both the schist and the serpentine carry some iron-bearing minerals and as much as a couple of percent of magnetite. These are responsible for the anomalies, but neither the rock composition nor the amplitude of the anomalies indicates any likely economic iron deposits.

It is noteworthy that only the oligoclase-mica variety of the Wissahickon creates these anomalies; just to the north from Paoli to Berwyn a parallel wide belt of the chlorite-albite variety of the Wissahickon produces no such magnetic pattern.

A small positive magnetic anomaly appears in Easttown Township, just north of Waterloo Mills, and a similar anomaly occurs in Radnor Township, just west of Ithan. Each of these is about 1 mile in diameter and each occurs over gabbroic gneiss. This gneiss carries considerable iron-bearing minerals as well as some magnetite. Neither the small amplitude of the anomalies, less than 200 gammas each, nor the rock composition suggests any likely economic iron deposits.

INFORMATION CIRCULAR 19. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, NORRISTOWN QUADRANGLE

NORRISTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 201

Only the western half of the Norristown quadrangle has been mapped aeromagnetically in this program. No distinctive magnetic trends can be noted.

A positive magnetic anomaly occurs in Lower Merion Township, about one-half mile south of West Conshohocken. The anomaly appears to trend in a northeast-southwest direction and is about a half mile wide and nearly 2 miles long. It is centered directly over a patch of hornblende gneiss which is surrounded by granite gneiss; the dark, hornblende-rich rock forms a topographic high. The hornblende gneiss contains considerable iron silicate minerals and up to a couple of percent of magnetite. It is these minerals, as well as the effect of the hill, which are responsible for the magnetic anomaly. Neither the magnitude of the anomaly, about 400 gammas, nor the rock composition is a favorable indication of economic iron concentrations.

In Upper Merion Township near Swedeland, there is a small positive magnetic anomaly which straddles the Schuylkill River. This is an industrial anomaly, related to the magnetic effect of factory installations. Two other small industrial anomalies are located along the Schuylkill River, one at Bridgeport and one southeast of Norristown.

In Radnor Township there is an east-west-trending positive anomaly just north of Radnor. This anomaly is located directly over a narrow belt of the Wissahickon Formation. The rock is primarily a mica schist, with some gneiss intermixed. There is a small amount of iron-bearing mineral in this rock which is responsible for the anomaly. However, neither the rock type nor magnitude of the anomaly can be considered at all encouraging as to economic iron concentrations.

INFORMATION CIRCULAR 20. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, MALVERN QUADRANGLE

MALVERN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 202

The magnetic contour map demonstrates a threefold division in the magnetic pattern over the Malvern quadrangle. An east-west belt in the center of the map shows only a few, simple, widely spaced magnetic contours. This pattern is developed over Cambrian and Ordovician sandstones and limestones. No magnetic complexities are indicated.

The northern and southern portions of the quadrangle demonstrate a somewhat more complex pattern of magnetic contours with variable spacing of the contours and a few magnetic highs and lows. These portions of the map involve crystalline rocks, both metamorphic and igneous.

An elongate, positive anomaly occurs in the southeast corner of the quadrangle, in East Goshen and Willistown Townships, about one mile south of Malvern. It is about half of a mile wide and cuts diagonally across the corner of the map in a northeast-southwest direction. This positive anomaly of about 300-gamma amplitude lies directly over a belt of serpentine, serpentinized pyroxenite, and serpentinized peridotite. These rocks have considerable iron silicate minerals as well as a few percent of magnetite. It is the effect of these iron-bearing minerals, plus those of the adjacent gabbroic mass, which is responsible for the positive magnetic anomaly. Recoverable, magnetic iron content of these rocks is only about two percent, far below any grade possible for economic mining consideration.

A fairly broad, positive magnetic anomaly occurs in the northeastern portion of the map in Charlestown Township, about 3 miles south of Phoenixville. The anomaly is nearly 3 miles long and over 1 mile wide; it has an amplitude of about 300 gammas. The anomaly area consists of gabbroic gneiss and lighter colored, more acid gneiss which was mapped as granodiorite (Bascom and Stose, 1938). Indications are that the gabbroic rock underlies the so-called granodiorite. These crystalline gneisses, particularly the gabbroic rock, contain numerous iron-bearing minerals, particularly magnetite in amounts up to about three percent, which are apparently responsible for the positive magnetic anomaly. The iron content, however, is far below mining requirements for economic mining and neither the amplitude of the anomaly or the nature of the rocks observable in the field offers any encouragement along that line.

INFORMATION CIRCULAR 21. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, WEST CHESTER QUADRANGLE

WEST CHESTER QUADRANGLE

U.S. Geological Survey Aeromagnetic Map G.P. 203

The aeromagnetic contour map of the West Chester quadrangle shows a linear belt of magnetic anomalies in the northwest corner and an area of circular and linear magnetic anomalies in the east-central part of the map. These two anomaly areas are separated by a northeast-trending belt which exhibits widely spaced contour lines and very few anomalies. This general magnetic picture corresponds to the known geological conditions. The distinctive anomaly areas are those underlain by Wissahickon schist and serpentine while the northeast-trending belt between is one consisting of gabbroic gneiss.

In the northwest corner of the quadrangle there is an elongate positive magnetic anomaly trending in a northeasterly direction in West Goshen Township, approximately 1 mile north of West Chester. It is about one-half mile wide and 3 miles long and shows either a branch or subsidiary anomaly at its western end which is almost within the city limits of West Chester. This anomaly lies directly over an area of Wissahickon oligoclase-mica schist and associated serpentine rock. Similar magnetic patterns occur over these same rock types wherever they occur in the area surveyed. The schist and serpentine contain considerable quantities of iron-bearing minerals, including a couple of percent of magnetite. The rocks have not demonstrated an iron concentration of economic magnitude and the relatively small amplitude of the anomaly, less than 300 gammas, indicates the iron concentration is noneconomic at this locality.

In the east-central part of the quadrangle, in Westtown Township, about 3 miles southeast of West Chester, three positive magnetic anomalies stand out. Each of these anomalies is nearly circular and less than 1 mile in diameter; the center one has the largest amplitude, a little over 500 gammas. The three anomalies all occur over a single elongate, lens-shaped area of Wissahickon gneiss and schist. Field examination indicates the rock is quite dark colored, due to considerable quantities of iron silicate minerals and also small amounts of magnetite. In other areas, both in this quadrangle as well as adjacent ones, this type of rock has been responsible for distinctive anomalies but in each case the shape of the anomaly is essentially the same as the area of the underlying rock. The contrast here in the West Chester quadrangle between the elongate lens-shaped area of Wissahickon rock and the three distinct, circular magnetic anomalies over the areas is a situation without a readily discernible geologic explanation. The size, shape, and amplitude of the anomalies indicates three specific causative features, each occurring at shallow depths (no more than 500 feet) under each anomaly. One possibility is that these are three cylindrical or finger-like masses of serpentine within the Wissahickon rocks. Serpentinized rock in southeastern Pennsylvania tends to give sharp anomalies; a good example of this occurs in the adjoining Media quadrangle. Another possibility, of course, is that there are three zones within the Wissahickon rocks which contain higher concentrations of magnetite, the iron oxide mineral. These anomalies offer a challenge for further investigation, though neither the amplitude or magnitude of the anomalies serves as a strong encouragement for the possibility of economic iron ore deposits.

Two elongate positive magnetic anomalies occur in East Goshen and Willistown Townships, about 4 miles northeast of West Chester. These anomaly areas trend northeast. They lie end to end, and are each less than half of a mile wide and 2 miles long. They both lie over a large area of gabbroic gneiss and the low amplitude of the magnetic anomalies, less than 150 gammas each, suggests that only a relatively minor increase in the amount of iron-bearing minerals present in the underlying rocks is responsible. No iron mineralization of economic possibility is at all likely.

INFORMATION CIRCULAR 22. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, MEDIA QUADRANGLE

MEDIA QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 204

The northwestern third of the magnetic contour map of the Media quadrangle exhibits widely spaced magnetic contours with no persistent or outstanding trend. This area is one which includes extensive areas of gabbroic gneiss and several belts of granitic gneiss. Neither of these rocks appear here to carry any significant magnetic concentration. The eastern half of the quadrangle, however, exhibits several elongate and circular magnetic anomalies and fairly close spacing of magnetic contour lines. This eastern portion of the quadrangle is composed of Wissahickon schist and gneiss as well as large masses of serpentine rock. These rocks are responsible for numerous anomalies and complex magnetic contour patterns in several parts of southeastern Pennsylvania.

An elongate positive magnetic anomaly extends for about 2 miles from Edgemont Township into Newton Township, near Florida Park. It is less than one-half mile wide and has an amplitude of less than 200 gammas. This anomaly corresponds with an area of serpentine rock which carries several iron-bearing minerals as well as a couple of percent of magnetite. The rock, however, shows no iron concentration of economic potentialities. This is further indicated by the low amplitude of the anomaly.

An oval, northeast-trending positive magnetic anomaly occurs about 3 miles west of Media, extending from Middletown Township into Edgemont Township. This anomaly is about 2 miles long and 1 mile wide and has an amplitude of about 400 gammas. The geologic map shows this to be part of a large area of gabbroic gneiss. Exposures of bedrock are few in this area, but hornblende schist and gabbroic gneiss may be observed. These contain numerous iron-bearing minerals as well as some magnetite which may be responsible for the anomaly. It is also possible that at a rather shallow depth there may be a mass of serpentine rock with some magnetite. The spacing of the contour lines suggests that the rock material responsible for the magnetic anomaly is a mass which is sloping downward to the southeast. This is a distinctive anomaly, yet its amplitude can be considered only moderate at most. In this general environment of crystalline and metamorphic rocks the outlook is not favorable for this anomaly area to carry any economic iron concentrations.

In the northeastern quarter of the quadrangle, four magnetic anomalies may be observed extending in a northeasterly direction from Sycamore Mills in Upper Providence Township. Each of these anomalies is oval shaped, less than 1 mile in diameter, and shows a maximum amplitude of about 300 gammas. Three of these anomalies occur over a large mass of gabbroic gneiss which is quite variable in composition. The fourth anomaly of this group, the most northeasterly one, occurs over a mass of serpentine rock which in many areas is known to contain small amounts of the mineral magnetite. The three anomalies over gabbroic gneiss may be due to magnetite and other iron-bearing minerals somewhat concentrated in the gneiss, or it is possible that these are bodies of serpentine rocks at a shallow depth beneath the surface of the gneiss. In general, neither the rock composition nor the amplitude of the anomalies offers any real encouragement for iron concentrations of economic scope.

A small, circular, positive magnetic anomaly occurs in Upper Providence Township, at Rose Tree, about 1 mile north of Media. The anomaly is less than 1 mile in diameter and has an amplitude of about 200 gammas. It occurs over a large, widespread area of Wissahickon schist and gneiss. This same variety of the Wissahickon Formation is responsible for similar anomalies in several other locations in southeastern Pennsylvania. Apparently there are small concentrations of magnetite and other iron-bearing minerals which are responsible for the anomaly, but such iron concentrations have not proved economically significant in the Wissahickon Formation and the small amplitude of this anomaly offers no further encouragement for development.

INFORMATION CIRCULAR 23. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, EAST GREENVILLE QUADRANGLE

EAST GREENVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 205

The East Greenville magnetic contour map exhibits a complex pattern with many distinct anomalies. To a considerable degree the magnetic map reflects the complex geologic nature of the area. The northwestern half of the quadrangle, which shows most of the anomalies, is a sharply rolling landscape underlain by crystalline rocks—metasediments and meta-igneous rocks. This area is particularly suited to an aeromagnetic survey inasmuch as there is an extensive record of iron mining here. Over 100 iron mines of various sizes operated at one time in the East Greenville and adjacent Manatawny quadrangles.

The southeastern half of the East Greenville magnetic map shows a less concentrated magnetic pattern. This area consists of Triassic sandstones and shales with intrusive diabase masses.

The most intense anomaly in the quadrangle occurs along the western edge of the map in Longswamp Township, extending southwest from Red Lion for nearly two miles. This anomaly, which extends onto the adjacent Manatawny quadrangle, has an amplitude of over 2000 gammas, one of the largest found in the entire aeromagnetic survey. The area encompassed by the anomaly is known as the Rittenhouse Gap district, which in the 1870's and 1880's was the site of over 100 mines which produced over half of a million tons of magnetite ore per year. D'Invilliers (1883) gives a fairly detailed account of the major mines, their extensive underground workings and the nature of the ore. This small area included such impressive operations as the Gery mine at the southern end, the large Rittenhouse mine, the Ginkinger mine, and the Millers Farm at the northern end near Red Lion. In each case these were initially open pit operations which eventually became underground tunnel and shaft workings. The magnetite ore zones tended to pinch and swell, attaining thicknesses up to 30 feet. Most of the gneissic country rock appears to be metasedimentary, though some of the gneissic layers may have had an igneous origin. The ore horizons in each case reportedly dipped about 60° to the southeast and within each horizon the ore tended to be concentrated shoots pitching to the northeast. The ore zones were followed in depth to around 150 feet where they were reportedly pinching out. The contact between ore zones and country rock tends to be transitional rather than sharp; ore samples can be collected which show all degrees of concentration from nearly pure magnetite to gneiss rich in quartz, hornblende, mica, and feldspar. Numerous reports of ore shipments from the various mines indicate an average iron content of about 45%. Phosphorous content appears to be quite low, though some mention is made in the old reports of titanium content. It is interesting to note that though the gneiss strikes to the northeast the mines of the Rittenhouse Gap line up in a north-south trend.

After an extensive examination of the Rittenhouse Gap region in 1918, a geologist estimated 400,000 tons of possible ore which would average 23 percent iron content. At that time the underground workings were somewhat more accessible than they are today and the report comments on the large number of lenticular ore zones and the gneissic country rock which invariably contains 5 percent magnetite even in the barren zones.

Today, many of the large open cuts and pits are still accessible but the underground workings are partially caved and flooded. The area is considerably overgrown so that some effort is required to locate the old workings.

The magnitude and amplitude of the Rittenhouse anomaly command serious attention. A major concentration of magnetite is indicated at a shallow depth, steeply dipping to the southeast. Further exploration and drilling may be warranted here to establish the actual size and grade of the ore zone.

About a mile northeast of Red Lion in Longswamp Township is a positive anomaly nearly a mile in diameter with an impressive amplitude of 1250 gammas. This is the site of a cluster of former iron mines of which the Meckley mine was best known. This magnetite concentration is along the same ridge as the Rittenhouse Gap occurrences and may represent a continuation of the same ore-bearing horizon in the gneiss. The anomaly indicates that a significant concentration of magnetite still exists, though its size and grade would have to be determined by further exploratory work. The indications are, however, that the iron concentration is at a greater depth than is the case at Rittenhouse Gap.

A large, oval, positive magnetic anomaly occurs in Lower Macungie Township two miles northeast of Seisholtzville. The anomaly covers an area two miles long and one mile wide and has an amplitude of nearly 1000 gammas. No old mines are recorded for the center of this area, although the Bittenbender and Gehman mines operated at the edge of the anomaly, just east of Seisholtzville. These mines were last worked in 1880 and each yielded over 100,000 tons of ore from ore horizons which dipped to the southeast and were up to 20 feet thick. The old reports indicate the grade ran as high as 45 percent iron content. This is an area of crystalline gneiss in which an anomaly of 1000 gammas in amplitude has less significance than in a sedimentary environment. Nevertheless, this anomaly indicates some concentration of magnetite, though it appears that the depth and grade may not be as favorable for economic possibilities. Here too, further exploration is needed to clarify the situation.

An elongate positive magnetic anomaly occurs near Sigmund along Furnace Hill in Upper Milford Township. This anomaly has an amplitude of nearly 400 gammas. In this environment of crystalline gneiss, such an amplitude would appear to indicate only a minor concentration of magnetite, even though only a mile to the northeast the old Schell mine yielded some ore before the turn of the century. A small anomaly just west of Old Zionsville marks what little mineralization is left at the Schell site. The Furnace Hill anomaly does not offer any encouragement for any remaining economic concentrations of iron.

One and one-half miles northeast of Sigmund in Upper Milford Township is a positive anomaly about one mile long and one-half mile wide, with an amplitude of 1000 gammas. This is a rather sharp anomaly and though no old mines are recorded at this locality, a magnetite concentration within the underlying crystalline gneiss is indicated. The source of the anomaly appears to be fairly symmetrical and steeply dipping.

A group of four small positive anomalies is shown in Upper and Lower Milford Townships in the vicinity of Milford Park, Powder Valley, Corning, and Hosensack Station. Each of these anomalies is associated with a topographic high point underlain by gneiss; the 100-gamma amplitude of each also indicates that no economically significant concentration of iron is present.

A fairly sharp positive anomaly occurs just east of Huffs Church in Hereford Township. The anomaly area is about a mile long and less than a half mile wide. This is an area where the gneiss is quite dark, due to various iron-bearing minerals; magnetite is present but only in small quantities and the amplitude of only 400 gammas in this environment of crystalline rock does not indicate favorable economic possibilities. Two weak anomalies occur a mile south and a mile southeast of Huffs Church. These have amplitudes of less than 200 gammas and are located over topographic high points of gneiss. No significant concentrations of iron are indicated.

A large, complex positive magnetic anomaly is centered just east of Dale in Washington Township. The overall anomaly area is more than two miles in diameter, has an amplitude of about 700 gammas, and appears to define a topographically high mass of gneiss. While the mass of gneiss itself has a small amount of magnetite disseminated through it, the high points of this large anomaly are due to magnetite concentrations which were once mined. The Sparr and Eline mines operated a half mile east of Dale in the 1870's, the ore coming from magnetite-rich zones in hornblende gneiss. The positive anomaly at Barto, two miles south of Dale, also marks an old iron mine of the same era and geologic setting; the records tell of a 150-foot shaft and a 6-foot ore bed dipping 65° southeast. While the anomalies in the Dale-Barto area mark some present magnetite concentration, the relatively gentle anomalies indicate that economically significant iron concentrations are not present.

A well-defined arcuate positive magnetic anomaly belt cuts across Upper Hanover Township in the southeast corner of the quadrangle. This elongate anomaly corresponds to the underlying outcrop of a diabase dike; the content of iron minerals, including magnetite, in the diabase is adequate to cause the 400-gamma anomaly. No economic magnetite concentration is indicated.

INFORMATION CIRCULAR 24. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, MILFORD SQUARE QUADRANGLE

MILFORD SQUARE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 206

The aeromagnetic contour map of the Milford Square quadrangle exhibits a series of elongate anomalies in the northwest and southeast corners of the quadrangle. The anomalies in the northwest corner of the map reflect the presence of crystalline gneiss in that area. The other anomaly areas on the map are associated with metamorphic zones in sediments which are in contact with diabase intrusives. The masses of diabase themselves, as well as the belt of Triassic sediments extending from southwest to northeast, do not appear to result in any distinctive magnetic patterns or anomalies.

Three positive anomalies occur in Lower Milford Township, northeast of Hosensack; one is just at the northeast edge of Hosensack, one is half of a mile east of Dinngerville, and one is over Chestnut Hill. These anomalies each trend in a northeasterly direction and have a magnitude of about 200 gammas. They lie over a mass of gneiss (Pochuck according to Miller and others, 1941) which is in fault contact with Triassic shales and sandstones and a small area of Tomstown Dolomite. The gneiss ranges from granitic to dark hornblende-rich rock. The three anomalies are located over fairly dark hornblende gneiss and generally correspond with topographic highs. The rock type and low amplitude of the anomalies do not indicate any economic concentrations of iron minerals.

A small positive anomaly, about 1 mile across, appears in Lower Milford Township, east of Hosensack. It straddles the Lehigh-Bucks County line and lies directly over a mass of Triassic diabase, a dense igneous rock which in some places is responsible for anomalies due to small amounts of magnetite. The low amplitude of the anomaly (less than 150 gammas) and the composition of the rocks involved do not indicate favorable economic possibilities here for economic iron concentrations.

A positive anomaly lies along the eastern edge of the quadrangle, just east of Milford Square in Milford Township. The overall anomaly extends for over 2 miles in a northeasterly direction and shows three peaks. The anomaly is related to Triassic diabase which has intruded the sandstones and shales. The three peaks of the anomaly actually occur over the sediments directly adjacent to the contact with the Triassic diabase. The anomaly thus appears to result from the composite effect of the diabase intrusive and the metamorphosed Triassic sediments. The low amplitude of the anomaly and the composition of the rocks involved do not indicate favorable economic possibilities for economic iron concentrations here.

Two elongate (east-west trending) positive anomalies occur just south of Trumbauersville in Milford Township. These are related to a tongue of Triassic diabase, though the peaks of the anomalies are over Triassic sandstones and shales on the north and south sides of the diabase tongue. The indications are that the metamorphism of the sediments imparted magnetic properties to the low iron content in the sediments. These anomalies have a low amplitude of about 200 gammas, which together with the rock types present does not suggest the likelihood of any economic iron concentrations.

An elongate, positive anomaly is located about 1 mile south of Hosensack in Lower Milford Township. The anomaly has an arcuate pattern and corresponds in form and position to an arcuate tongue of Triassic diabase which has intruded the sandstones and shales. The anomaly has a small amplitude of about 200 gammas and appears to be attributable to the underlying diabase. Neither the amplitude nor the rock types indicate any economic concentrations of iron minerals.

INFORMATION CIRCULAR 25. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, SASSAMANSVILLE QUADRANGLE

SASSAMANSVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 207

The Sassamansville magnetic contour map exhibits considerable variation in magnetic pattern but there is a general correlation with the known geology. The linear anomalies in the southern and northern portions of the map mark the effects of diabase masses in those areas. The center third of the map is a belt of widely spaced anomalies; this is an area underlain by a thick series of Triassic sandstones and shales.

An elongate, slightly arcuate belt of positive magnetic anomalies about a half mile wide extends across the southern part of the quadrangle, from Upper Pottsgrove Township to Lower Frederick Township. Three or four magnetic peaks show up along this extensive anomaly, the highest just southeast of Fagleysville with an amplitude of nearly 500 gammas. This elongate anomaly lies over a belt of diabase tending to be along the northern edge of the exposed diabase sheet, where the igneous rock is thicker and has developed numerous topographic high points. Positive magnetic anomalies over diabase intrusives are often the result of numerous iron-bearing minerals present in the rock, particularly magnetite in small quantities. The fairly sharp anomaly peak southeast of Fagleysville probably marks a higher concentration of magnetite, but neither the amplitude nor the rock type offers favorable possibilities for an economic iron concentration.

Sassamansville in New Hanover Township is located at the end of an elongate positive magnetic anomaly with a double peak. One high point a half mile to the southeast has an amplitude of 300 gammas and a second peak 1½ miles southeast of Sassamansville has an amplitude of 350 gammas. The double-peaked anomaly occurs over Triassic sandstones only a short distance from a large diabase intrusive. The anomaly is due to a magnetite concentration produced by the effect of the diabase, but the amplitude and magnitude of the anomaly indicate the source is fairly deep and probably too low a concentration to be economic.

In the northeast corner of the quadrangle astride the Colebrookdale-Washington Township line is an elliptical positive magnetic anomaly about 1½ miles long with an amplitude of 500 gammas; this is the location of the Bechtelsville anomaly described by Hawkes of the U. S. Geological Survey in 1945. He concluded that there were some small magnetite concentrations at a shallow depth and a large concentration more deeply buried. Spencer (1908) indicates that the ore occurred as a replacement of limestone conglomerate interbedded with Triassic shales and sandstones. The anomaly indicates that a significant concentration of magnetite still exists here. This is an unusual geologic area where Triassic diabase is in contact with Triassic limestone conglomerate and lower Paleozoic carbonate rocks. The answer to just how large the iron concentration is will have to await further exploration; the favorable conditions here merit further consideration.

INFORMATION CIRCULAR 26. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, PERKIOMENVILLE QUADRANGLE

PERKIOMENVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 208

The aeromagnetic map of the Perkiomenville quadrangle exhibits very few widely spaced magnetic contour lines in the eastern half. This reflects the fairly homogeneous Triassic sandstones and shales in that area. The western half of the map shows some distinct elongate magnetic anomalies which are directly related to contact metamorphic zones of diabase intrusives in that area.

An elongate positive magnetic anomaly occurs in Marlborough Township, about 1½ miles north of Perkiomenville. The anomaly is about one-half mile wide and extends for about 3 miles in an east-west direction. The anomaly lies over an area adjacent to a tabular mass of diabase which is exposed in a belt 1 to 2 miles wide. The anomaly occurs over sedimentary rocks, sandstones and shales, which have been metamorphosed by the adjacent and underlying diabase intrusive. There is also in the anomaly area a thin tongue of diabase which is an offshoot of the large nearby diabase mass. The anomaly is primarily the result of small amounts of finely disseminated magnetite in the sandstones and shales formed by metamorphism of the sedimentary iron minerals. The siliceous nature of the sandstones and shales, the underlying diabase, and the relatively low 400-gamma amplitude of the anomaly are unfavorable indications as to economic iron possibilities.

An elongate positive magnetic anomaly occurs in the southwest quarter of the quadrangle, in Lower Frederick and Upper Salford Townships, south of Zieglerville. This is an elongate anomaly, extending on the map for about 3 miles in length and about half a mile in width; the high point is at Spring Mountain. This anomaly has the same general geological setting as the one discussed above. It is located over metamorphosed Triassic sandstones and shales which are adjacent to a diabase intrusive mass. The alteration of the sediment has resulted in finely disseminated magnetite which appears to be the primary cause of the anomaly. The amount of iron present is very low and the rock types involved, as well as the 200-gamma amplitude of the anomaly, are not indicative of favorable possibilities for an economic iron deposit.

INFORMATION CIRCULAR 27. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, PHOENIXVILLE QUADRANGLE

PHOENIXVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 209

The magnetic contour map of the Phoenixville quadrangle has only a few contour lines and no magnetic anomalies of geologic origin. This denotes an area of uniform magnetic properties. Except for the far southwest corner, the quadrangle is underlain by Triassic sandstones and shales. Even the crystalline gneisses in the southwest corner of the quadrangle do not show enough magnetic intensity or contrast to make any significant magnetic pattern. There is, therefore, no evidence of any significant iron concentration in this quadrangle.

Several magnetic anomalies due to industrial installations may be observed on the map. These occur at Phoenixville, near Cromby, near Linfield, and just south of Pottstown.

INFORMATION CIRCULAR 28. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, ALLENTOWN QUADRANGLE

ALLENTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 213

The northern half of the Allentown quadrangle magnetic contour map shows one large, relatively simple anomaly. The southern half of the quadrangle exhibits a large number of anomalies of various sizes, shapes, amplitudes, and orientations. This variation in magnetic pattern reflects the difference in geology between the two halves of the quadrangle. The northern half of the quadrangle is an area of sedimentary rocks with only a few broad folds and minor faults. The southern half of the Allentown quadrangle is manifested by igneous, metamorphic, and sedimentary rocks, all deformed by numerous folds and faults.

A large positive magnetic anomaly, about 9 miles long and 5 miles wide, is centered over Hanoverville and includes parts of Hanover, East Allen, Bethlehem and Lower Nazareth Townships. This closed anomaly has an amplitude of 500 gammas; this indicates a significant high point in the magnetic attraction of the underlying rocks. However, the wide spacing of the magnetic contour lines within the anomaly indicates a depth of about 1 mile to the source of the anomaly. The anomaly appears to be due to either a broad protuberance of the buried crystalline rocks beneath the sediments or to a magnetic concentration within the buried crystallines. Just how much of an iron concentration may exist is impossible to determine from the magnetic picture, but the great depth which is indicated suggests that even if there were an unusually high concentration, mining would be economically and technically prohibitive.

The most pronounced positive magnetic anomaly in the Allentown quadrangle is located just north of Vera Cruz Station in Upper Milford Township. This oval-shaped anomaly trends northeasterly, has an amplitude of about 1800 gammas, and is about 1½ miles long and less than 1 mile wide. The anomaly occurs along the southern edge of an extrusive belt of Precambrian gneiss which ranges in composition from granite gneiss to hornblende gneiss. Within this gneiss are bands rich in magnetite. At one time the gneiss was considered to be entirely of igneous origin. Today it is believed by many that at least part of the gneiss is highly metamorphosed sedimentary rock and that some of the banding is indicative of the original sedimentary layers.

The Vera Cruz area has a history of mining of magnetite ore that dates back to pre-Civil War years. The last mining attempt was made during the First World War. At least eight mines have operated in this one area at various times and it is estimated that in total they produced over 300,000 tons of ore. Most of the mines were underground operations with shafts and extensive tunnels. A number of iron ore furnaces in the area were maintained by the local ore. Over one part of the Vera Cruz area Thomas A. Edison directed a detailed ground magnetic survey (Miller and others, 1941) which helped to clarify the nature of the iron mineralization.

The aeromagnetic anomaly at Vera Cruz indicates the anomaly source is at a shallow depth of less than 500 feet, and occurs in a mass which has a steep side to the northwest and a gentle slope to the southeast. This fits the general picture which has evolved from the mines of the area as well as the Edison ground magnetic survey. The gneiss contains what have been variously called tabular bodies, beds, and veins which are rich in magnetite grains intermixed with quartz, plagioclase feldspar, and varying amounts of pyrite, hornblende, mica, and chlorite. Several such magnetite-rich veins are known in the Vera Cruz area; they dip (slope) to the south at about 45° and have been found to extend laterally for as much as 1½ miles. Though these veins are generally parallel to each other, some unite and some pinch out. The magnetite-rich veins have a maximum thickness of 15 feet, no vein maintaining a constant thickness. A horizontal tunnel at the old Jobst Mine showed a distance of over 250 feet between successive veins. Miller and others (1941) give analyses of samples taken during the days of active mining. These show the iron-rich veins to average 42 percent iron while the more barren gneiss between the magnetite zones averaged 18 percent iron. There is some question as to whether these old analyses dealt with recoverable iron or total iron—a total iron figure would be misleadingly high inasmuch as nonrecoverable iron present in silicate minerals would be included. Recent sampling in the Vera Cruz area has indicated the maximum recoverable iron content in the magnetite-rich zones to be on the order of about 30 percent. The early analyses show an average of 35 percent silica content in the ore zones and mention the presence of some titanium; both of these are objectionable in excess quantities.

The old reports on the Vera Cruz area indicate that the mines only worked the ore at shallow depths above the water table, a limitation which has been somewhat removed today by improved pumping techniques.

The airborne magnetic anomaly at Vera Cruz indicates that significant magnetite mineralization still exists there. However, it will require extensive exploration to ascertain the economic possibilities of that location. Tonnage and average ore grade would have to be established by extensive drilling. It will be necessary to resolve the feasibility of mining iron-rich zones which are steeply inclined, and which have very variable thickness, the maximum known to date being 15 feet. However, Edison's old idea of mining both the iron-rich zones and the intervening lean zones merits reconsideration in this area. There is often a tendency to pass over an area which has been mined and abandoned. The intensity of the Vera Cruz anomaly suggests this location merits careful reexamination.

The Allentown magnetic contour map shows a series of positive magnetic anomalies along South Mountain in Salisbury, Upper Saucon, and Lower Saucon Townships. One such anomaly occurs about 1½ miles northeast of Emmaus and straddles the Salisbury-Upper Saucon Township line. This area of closure is oval shaped, about 2 miles long and 1 mile wide and has an amplitude of about 400 gammas. Approximately 1 mile farther to the northeast along the same Salisbury-Upper Saucon Township line are four positive magnetic anomalies, each less than 1 mile in diameter and each with an amplitude on the order of 400 gammas. Another such anomaly occurs in Salisbury Township, about a mile northwest of Colesville. Farther north on South Mountain there is a small anomaly at Seidlersville, another about a mile northeast of Seidlersville, still another near Iron Hill, about 2 miles northeast of Seidlersville. Two other positive magnetic anomalies occur at the northern end of South Mountain, each located about 1 mile south of the Lehigh River; one is at Farmington and the other is at Fountain Hill. All of these relatively small anomalies on South Mountain occur at or near topographic highs and over gneissic rock which varies in composition in different places from granitic gneiss to hornblende-biotite gneiss. This is an extension of the same rock type which occurs at Vera Cruz with magnetite-rich zones. However, the size and amplitude of these South Mountain anomalies indicate that any magnetite concentration which may be responsible for each is quite limited in both area and degree of iron concentration. Unlike the Vera Cruz situation, these South Mountain anomalies appear to offer relatively little opportunity for economic development.

A more impressive positive magnetic anomaly occurs near Franklin School in Upper Saucon Township about a mile southwest of Spring Valley. The anomaly area is over 1 mile long and nearly 1 mile wide; the amplitude of nearly 1000 gammas is one of the highest in the quadrangle. The spacing of the magnetic contours indicates a fairly shallow source for the anomaly. The high point of the anomaly lies in a valley at the foot of Saucon Hill, just west of Franklin School. This anomaly is somewhat irregular in shape and has three separate high points, which indicates some complexity in the magnetic source. The area under the anomaly consists of a mass of gneiss which is flanked by sandstone and dolomite; the gneiss forms the core of an anticline. It is noteworthy that Saucon Hill, just to the north, exhibits no anomaly despite the fact that it is a pronounced topographic feature made up of similar crystalline gneiss. This indicates that it is not just simple contact between gneiss and sediment which is responsible for the Franklin School anomaly, but rather that there must be a fairly concentrated magnetic source. Miller and others (1941) report that prior to 1883 the Eichelberger and Frey mine produced some 4000 tons of magnetite ore at the foot of Saucon Hill, a few hundred feet north of this anomaly. That old mine was apparently producing from a magnetite-rich zone in the gneiss and it appears likely that the nearby anomaly under discussion is also the result of a magnetite concentration in the gneiss. It will require further exploration to determine the size and degree of iron mineralization present.

In the eastern third of the Allentown quadrangle, there is a group of positive magnetic anomalies, all lying over a complex area of gneiss. At Bitts Hill in Springfield Township, there is an anomaly less than a mile in diameter with an amplitude of about 600 gammas. This is the site of a small, abandoned magnetite prospect. On the Bucks-Northampton County line, about a mile north of Springtown, is a small anomaly half a mile in diameter and about 300 gammas in amplitude. In Lower Saucon Township, about a mile west of Springtown, is an anomaly approximately half a mile in diameter with an amplitude of about 250 gammas. Near Swoveberg in Lower Saucon Township, there is an elongate anomaly, about 1 mile long, with an amplitude of 700 gammas. Miller and others (1941) report an abandoned pit in two feet of high-grade magnetite a couple of hundred feet west of the peak of this anomaly. About half a mile north of the town of Lower Saucon is an elongate anomaly, about 2 miles in length, with an amplitude of 700 gammas. Approximately a mile southwest of Redington, near the Lehigh River, is an anomaly nearly a mile in diameter with an amplitude of 400 gammas. Each of these anomalies in the eastern half of the Allentown quadrangle appears to be the result of a magnetite concentration within the banded gneiss; the linear anomalies are all elongate in the direction of the gneissic banding, that is, to the northeast. Each of the anomalies of this group is associated with a topographic high and the relatively limited amplitudes do not favor the possibility of economic iron concentrations in this part of the quadrangle.

Two anomalies of nongeologic origin appear on the map; both of these are industrial anomalies. One is over the Bethlehem Steel Company plant at the southern edge of Bethlehem and the other is near the center of Allentown.

INFORMATION CIRCULAR 29. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, QUAKERTOWN QUADRANGLE

QUAKERTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 214

The Quakertown aeromagnetic contour map exhibits relatively few, widely spaced contour lines except for an arcuate belt of positive anomalies extending from the southwestern corner to the northeastern corner of the quadrangle. This belt corresponds with the upper contact zone of a tabular mass of diabase. It is noteworthy that in this quadrangle neither the diabase itself nor the wide areas of Triassic sediments which make up most of the quadrangle exhibit any distinctive magnetic pattern or significant anomalies.

An elongate positive anomaly, about 3 miles south of Quakertown, occurs along the southern edge of Richland Township. It extends from the western edge of the quadrangle for about 3 miles in an east-northeast arc approximately one-half mile wide. This anomaly lies along the northern edge of a Triassic diabase intrusive sheet which has an outcrop width of about 2 miles. The anomaly lies over Triassic sandstones and shales which have been metamorphosed by the adjacent and underlying diabase intrusive. The metamorphism of the sediments altered their color from red to black, and formed finely disseminated magnetite from the original sedimentary iron content. The contact zone under this anomaly also is cut by a thin sheet of diabase which may contribute to the anomaly. The anomaly has an amplitude of about 400 gammas and is quite conspicuous on the map. Nevertheless, the amplitude of the anomaly, the nature of the diabase, and the siliceous sandstones and shales are all unfavorable in relation to possible economic iron-bearing deposits.

Three positive anomalies, each about 1 mile in diameter and about 100 gammas in amplitude, occur in the northeastern quarter of the Quakertown sheet. One is in Richland Township, just west of Richland Center; a second is in Haycock Township, about 1½ miles north of Richland Center and the same distance east of Quakertown; a third is in Haycock Township, just west of the town of Applebachsville. Each of these three small anomalies lies directly over the contact between the broad diabase intrusive mentioned above and adjacent Triassic sandstones and shales. Contact metamorphism of the sediments is evident from the darkened sediment, resulting from deoxidation of the small amount of original sedimentary iron oxide to form minute, disseminated grains of magnetite. The very low magnitude of these anomalies and the physical characteristics of the rocks involved indicate very low iron content and unfavorable possibilities for economic iron deposits.

About 2 miles northwest of Quakertown in Richland Township is a northeast-trending positive anomaly. It is less than half a mile wide, extends for about 2 miles on this map, and has an amplitude of 250 gammas. This is an extension of an anomaly which occurs in the Milford Square quadrangle to the west. The anomaly is developed over the upper contact between a sheet of diabase and adjacent Triassic shales and sandstones. Metamorphism of the ferruginous sediments has produced a small magnetite content. The small amplitude of the anomaly and the siliceous nature of the sediments do not indicate an economic concentration of iron.

INFORMATION CIRCULAR 30. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, BUCKINGHAM, LAMBERTVILLE AND STOCKTON QUADRANGLES

BUCKINGHAM, LAMBERTVILLE & STOCKTON QUADRANGLES

U. S. Geological Survey Aeromagnetic Maps G. P. 215 & G. P. 216

The magnetic contour maps of the Buckingham, Lambertville and Stockton quadrangles present a striking magnetic pattern. The maps are dominated by a large magnetic anomaly which trends northeasterly along Buckingham Mountain. Inasmuch as the rocks at the surface of Buckingham Mountain and adjacent Buckingham Valley are considerably different in age and lithology from the surrounding area of Triassic sediments, it might be expected that a contrast in magnetic intensity would exist. Yet the Buckingham Mountain anomaly is so large in magnitude and amplitude that it merits careful consideration for its structural and mineralogical implications.

Buckingham Mountain and adjacent Buckingham Valley are made up of Cambrian and Ordovician sediments. The mountain ridge consists of very hard, erosion-resistant Chickies quartzite, while the adjacent valley to the north consists of limestone. Both the limestone and the quartzite have been quarried in many places in the Buckingham area for crushed stone. The occurrence of this isolated area of lower Paleozoic sediments in the center of the broad Triassic belt is a fairly definite indication of a major structure which has brought the older rock up against the younger Triassic sediments.

The positive magnetic anomaly which extends along Buckingham Mountain from Buckingham to Solebury Township is probably due to a ridge of Precambrian crystalline rocks which underlie the Paleozoic sediments of Buckingham Mountain at a relatively shallow depth—actually these crystallines are exposed at one point east of the town of Buckingham Valley. The size and amplitude of the Buckingham Mountain anomaly indicate that the crystalline ridge extends for at least 4 miles. Along the southeastern flank of Buckingham Mountain is a major fault which, on the basis of the magnetic data, has a vertical displacement of at least 3000 feet. It is this fault displacement of the crystalline basement rocks which is largely responsible for the Buckingham Mountain anomaly.

The Buckingham Mountain anomaly, however, appears to have other complexities. It is to be noted that along the eastern edge of the Buckingham quadrangle, in the vicinity of Glendale and Lahaska Station, two small anomaly areas appear to distort the overall Buckingham Mountain magnetic picture. It is possible that these may be due to a subsurface occurrence of the Solebury Mountain diabase against the faulted crystallines beneath Buckingham Mountain.

Along the western edge of the Lambertville quadrangle, a significant anomaly appears to be superimposed on the northeastern end of the Buckingham Mountain anomaly in the vicinity of Aquetong and Aquetong Lake. This anomaly has a magnitude of over 9260 gammas, which is several hundred gammas higher than any other portions of the Buckingham Mountain anomaly. The Aquetong feature appears to be fairly well localized, as the area of magnetic closure there is less than 1 mile in diameter; the spacing of the magnetic contour lines suggests a shallow mass which is less than 500 feet deep. This Aquetong area shows no metallic mineralization at the surface; unmetamorphosed Cambrian limestones are in fault contact with Triassic sandstones and shales. This anomaly could be caused by a magnetite concentration or by a mass of diabase, but there is no apparent surface indication of either. With the presence of limestones, the possibility of significant magnetite mineralization is challenging. This area merits further research and exploration.

In the Lambertville quadrangle, magnetic anomalies occur over Solebury Mountain and Jericho Mountain. These mountains are made up of diabase which is responsible for the magnetic anomaly due to its topographic expression and the content of magnetite and other iron-bearing minerals. While the magnetic contours shed some light on the form of the diabase masses, no significant iron concentration is indicated in the case of these two mountains.

INFORMATION CIRCULAR 31. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, SAFE HARBOR QUADRANGLE

SAFE HARBOR QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 217

The aeromagnetic contour map of the Safe Harbor quadrangle exhibits only a general correlation with the geologic map of the same area. The northern third of the magnetic map has only a few widely spaced contour lines, which indicates rocks of uniform magnetic intensity. This part of the quadrangle is underlain chiefly by Conestoga limestone.

The southern two-thirds of the magnetic map shows an irregular spacing of contour lines with many small anomalies, but no distinctive trend is indicated. This is an area of Wissahickon schist and the irregular magnetic pattern reflects the variability of both composition and structure within the schist.

A small positive magnetic anomaly occurs on the east bank of the Susquehanna River about one mile south of Turkey Hill in Manor Township. The anomaly area is about a mile long and the amplitude is nearly 400 gammas. This is an area of Wissahickon schist which from place to place has been found to contain concentrations of iron silicate minerals as well as up to a few percent of magnetite. Neither the size nor the amplitude of the anomaly, nor the mineralogical nature of the Wissahickon schist in this area offers encouragement as to the probability of an economic iron concentration.

Several positive magnetic anomalies occur in the southern portion of the quadrangle. One occurs about a mile west of Lucky in Chanceford Township. This is not a sharp anomaly; it has an amplitude of about 150 gammas. Just west of Battle Hill School in Chanceford Township is a positive anomaly about a mile long, with an amplitude of 250 gammas. A small, sharp, elliptical anomaly with an amplitude of 300 gammas occurs 1½ miles southwest of Lucky in Chanceford Township. All of these anomalies originate over Wissahickon schist, apparently due to local concentrations of iron-bearing minerals including magnetite. Neither the rock type nor the amplitude of the anomalies indicates any iron concentrations which are likely to be of economic scope.

At the Safe Harbor Dam is a positive magnetic anomaly of nongeologic origin; it is caused by the power-house installation at the dam.

INFORMATION CIRCULAR 32. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, CONESTOGA QUADRANGLE

CONESTOGA QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 218

The contour patterns on the aeromagnetic map of the Conestoga quadrangle show a fairly close correlation with geologic patterns which have been mapped in that area. The northern third of the magnetic map exhibits only a few, very widely spaced contour lines, indicating rock of uniform magnetic intensity; this is an area underlain by Conestoga limestone of Ordovician age.

The southern third of the quadrangle exhibits a linear magnetic pattern trending in an east-northeasterly direction; this area is underlain by Wissahickon schist and the linear pattern reflects the schistosity. In this area one positive magnetic anomaly with an amplitude of about 300 gammas extends for 4 miles from just south of Pequea to 2 miles east o Mt. Nebo in Martic Township. A small circular anomaly, about half a mile in diameter and 200 gammas in amplitude, occurs just west o Rawlinsville in Martic Township. These two anomalies reflect smal variations in iron-bearing minerals in the Wissahickon schist, but they do not in any way indicate any iron concentrations of economic potential

The central third of the magnetic map shows complexities of pattern which are an excellent reflection of very complex geologic structure which has been found to exist in that area. Three distinct anomalies stand out One anomaly is located along Pequea Creek northwest of Marticville in Martic Township. The anomaly area is approximately 2 miles long and half a mile wide and it trends in a northeasterly direction over a bel of Antietam-Harpers schist. This is in the vicinity of an old iron prospec which yielded some fairly high concentrations of magnetite from th Antietam Formation. The anomaly suggests a steeply dipping, narrow band of magnetic material at a very shallow depth. The amplitude o less than 800 gammas raises the question of whether the concentration of magnetite is of economic potential. Further exploration is needed t clarify this situation.

In Conestoga Township, about 2 miles west of Marticville, are two parallel, elongate anomalies similar in character (and probably of th same origin) to the Pequea Creek anomaly described above. These anomalies have an east-west trend. The more northerly one is located at the town of Conestoga, is less than a mile long, and has an amplitude of 250 gammas. The more southerly anomaly is about 2 miles long and extends westward to Safe Harbor; it has an amplitude of 900 gammas These two anomalies are located over Antietam-Harpers schist, a folded continuation of the same rock unit responsible for the Pequea Creek anomaly described above. It is likely that these anomalies are caused b concentrations of magnetite in the Antietam-Harpers schist. The smalle of these two anomalies offers no encouragement as a possible economi iron concentration. The larger Safe Harbor anomaly source appears t be quite shallow at its eastern end; with an amplitude of 900 gamma this area merits further exploration to clarify the degree and size of iron concentration.

INFORMATION CIRCULAR 33. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, QUARRYVILLE QUADRANGLE

QUARRYVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 219

The magnetic pattern displayed on the aeromagnetic contour map of the Quarryville quadrangle shows only a general correlation with the geologic pattern which has been mapped in that area.

The northern half of the aeromagnetic map shows a few very widely spaced contour lines, indicating rocks of uniform magnetic intensity. The geologic map of the same area shows mainly limestones and dolomites with lesser areas of quartzite and phyllite, all involved in narrow, east-west-trending folds.

An area with an irregular contour pattern and small anomalies occurs in the southwest corner and along the southern boundary of the quadrangle. This corresponds with the outcrop pattern of a chloritic variety of Wissahickon schist. The small size and amplitude of the anomalies in this area suggest that no significant iron concentrations are present. The minor magnetic variations, however, do help to delineate the schistosity of the Wissahickon Formation.

This aeromagnetic contour map is dominated by a large east-west-trending positive magnetic anomaly in the center of the quadrangle. The anomaly is located 2 miles north of Quarryville, on the boundary between Providence and Eden Townships. It is approximately 3 miles long and nearly a mile wide. The anomaly shows a very steep magnetic gradient, with an amplitude of approximately 1300 gammas. This is not a simple anomaly; there are at least two distinct peaks which are separated in such a manner as to suggest two magnetic sources, possibly due to faulting or folding. This complex anomaly occurs over an area of Antietam and Harpers quartz-albite-biotite-chlorite schist located on the nose of an anticline which plunges to the southwest. Cloos (1941) notes that the complexities of metamorphism, lithologic variability and structural complexity make it impossible to distinguish between these two formations in this area. It has been found, however, that there are varying amounts of magnetite in these Lower Cambrian rocks. Knopf and Jonas (1929) report an attempt to mine a magnetite concentration along Pequea Creek, about 5 miles west of this particular anomaly. There are several other localities in this region where coarse grains of magnetite have been found concentrated in the Antietam Formation. The sharpness of the magnetic gradient and the sizable amplitude of the anomaly suggest that a concentration of magnetite may be responsible, possibly localized within a layer of the schist. The indications are that the anomaly source is at a shallow depth. It will require further exploration to establish the grade and amount of iron concentration responsible for this interesting anomaly.

INFORMATION CIRCULAR 34. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, MORGANTOWN QUADRANGLE

MORGANTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 220

The Morgantown aeromagnetic contour map exhibits a distinct arcuate belt of closely spaced magnetic contour lines extending across the center of the map. North of this belt the map has only a few widely spaced contours denoting rocks of fairly uniform magnetic intensity; this is an area underlain by a thick series of Triassic sandstones and shales. The southern third of the map also has a few widely spaced magnetic contours, but this area is underlain by a relatively thin sequence of Triassic sediments as well as a belt of lower Paleozoic limestones.

The most prominent feature of the central belt of high magnetic intensity is the outstanding anomaly one mile north of Morgantown in Caernarvon Township. This more or less circular anomaly of some 1200 gammas in amplitude is located over the Bethlehem Steel Company's newly developed Grace Mine. This is a large iron ore deposit which was discovered only ten years ago by an airborne magnetometer survey. The ore consists of magnetite, which has replaced lower Paleozoic limestones that lie under the Triassic sandstones and shales. This is a large, high-grade orebody, but the fact that the ore comes no closer than 1400 feet to the surface is testimony to the effectiveness of airborne magnetic surveying.

About one mile northwest of Morgantown and one mile southwest of the Grace Mine anomaly is the site of the old Bylers magnetite mine which was developed at the contact between diabase and limestone; the magnetic map shows no indication that much or any ore was left unmined.

Extending westward from the Grace Mine anomaly is an elongate positive anomaly about a half mile wide; it extends across the quadrangle and swings north to a point near Alleghenyville in Brecknock Township. This anomaly is developed along the upper (northerly) contact of a northerly dipping intrusive sheet of diabase. The anomaly appears to result from the effect of a small amount of magnetite developed by contact metamorphism in the adjacent ferruginous sediment. However, nowhere along this elongate anomaly is either the magnitude or the amplitude (400 gammas maximum) at all comparable to the Grace Mine anomaly, nor is there any indication of even a lesser iron concentration of economic potential in this quadrangle.

INFORMATION CIRCULAR 35. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP, ELVERSON QUADRANGLE

ELVERSON QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 221

The Elverson aeromagnetic contour map exhibits a pattern of magnetic lines which relates fairly well with the known geological conditions of the area. An east-west-trending belt of distinct, elliptical anomalies across the south-central portion of the map corresponds with a belt of old iron mines.

The southern edge of the map shows only a few widely spaced anomalies despite a considerable variety of rock formations which have been mapped there. This indicates that those rocks are uniform in their magnetic intensity and that there are no indications of iron concentrations there.

The northern half of the quadrangle, except for the northeast corner, shows very few magnetic contours; it is an area underlain by a thick sequence of Triassic sandstones and shales.

Cutting diagonally across the northeast corner of the map in Union Township is an elongate positive magnetic anomaly over a half mile wide and extending for about four miles on this map. The anomaly is located directly over the outcrop belt of a dipping diabase dike. The high points of the anomaly are centered over the diabase. The diabase contains a considerable amount of iron-bearing minerals, including some magnetite, which are responsible for the magnetic anomaly. There is no indication in this area that contact metamorphic effects have increased the magnetic intensity of the adjacent sediments. The anomaly over the diabase has a maximum amplitude of 300 gammas, which together with the nature of the rock type does not offer any encouragement for economic concentrations of iron.

A little less than a mile southeast of Joanna in Caernarvon Township is a small, sharp, positive magnetic anomaly. It is about 1000 feet in diameter and has an amplitude of 600 gammas. This is the location of two former small iron mines, the Jones and Kinney mines; a couple of water-filled pits within the anomaly area mark the locations of those old workings. These mines have been described by Spencer (1908). The magnetite ore replaced limestone which is here in contact with diabase. The anomaly indicates that a definite concentration of magnetite still exists at a relatively shallow depth at this location. However, the size of the iron ore concentration appears to be fairly small; just how large it is or what the ore grade is would have to be resolved by exploration drilling.

A half mile south of Joanna, and only a half mile west of the Jones-Kinney anomaly described above, is a circular positive magnetic anomaly nearly a half mile in diameter with an amplitude of 250 gammas. No former mine is recorded at this location. The surface rock is diabase, which may be fairly thin here and could be underlain by either sandstone or limestone. This anomaly strongly suggests a magnetite concentration, but the low amplitude and gentle gradient of the anomaly are not encouraging as to ore grade or depth. Here too, more exploratory work would clarify the picture.

Two elliptical positive magnetic anomalies occur within a half mile of Elverson; one is due east and the other is to the south. Each of these is a half mile long. The more southerly one occurs over a point where metamorphic gneiss, igneous quartz monzonite, and sedimentary sandstone all meet. The more easterly of these two anomalies occurs over the contact of quartz monzonite with Triassic sandstones. Neither of these environments is conducive to major iron concentrations and the low amplitude of the anomalies does not suggest any significant concentrations.

About a mile west of the town of Warwick is a somewhat elliptical positive anomaly nearly a mile in diameter with an amplitude of 350 gammas. This anomaly is located over the site of the old Hopewell iron mine described by Bascom and Stose (1938); the mine was closed in 1914 when the ore was reported exhausted. The magnetite ore occurred as a replacement of a bed within Pickering gneiss; the ore-bearing layer reportedly averaged 30 feet in thickness and dipped to the northwest. The anomaly indicates that some magnetite still remains, but the relatively small amplitude and gentle gradient of the anomaly are not encouraging as to economic possibilities.

A half mile east of Pine Swamp in Warwick Township the map shows a sharp, nearly elliptical anomaly; it is nearly a mile long, three quarters of a mile wide and has an amplitude of a little over 1000 gammas. Though not quite as large in area or amplitude as the Grace Mine anomaly, it comes closer to it than any of the other anomalies in this district. Bascom and Stose (1938) report two abandoned iron prospects within a mile to the northeast—in both cases the ore zones were replacements of calcareous beds within the Pickering gneiss. This impressive Pine Swamp anomaly lies on ground which has been owned by an active mining company for several years.

A half mile east of the town of Warwick, the map shows the peak of a fairly broad but gentle positive anomaly; the amplitude is only about 200 gammas. This is within a few hundred feet of the location of the old Warwick iron mine described by Bascom and Stose (1938). It is reported that the mine was worked for over 100 years; both surface pit and underground workings were developed. The magnetite ore zone was a shallow bed of variable thickness, reaching a maximum of 25 feet and is reportedly (Spencer, 1908) a replacement of a calcareous bed within the Triassic sandstones. The low amplitude of the anomaly tends to support the historical accounts which indicate that most of the good ore was mined out at this locality. The present indications do not offer encouragement for any more economic iron concentrations at this locality.

INFORMATION CIRCULAR 37. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAPS, POTTSTOWN, WAGONTOWN, DOWNINGTOWN, COATESVILLE, UNIONVILLE, HONEY BROOK, AND PARKESBURG QUADRANGLES

POTTSTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 222

The Pottstown aeromagnetic map exhibits a marked correlation of magnetic contour pattern to geologic map pattern. The northeastern portion of the magnetic map shows essentially no contour lines, denoting no variations in magnetic intensity; that area is underlain by a thick sequence of Triassic sandstones and shales.

The more complex magnetic patterns in the western and southern portions of the map reflect the diabase and the older crystalline masses in those areas respectively.

An elongate, positive magnetic anomaly extends southeastward to a point about a mile east of Harmonyville in South Coventry Township and then swings to a southwesterly trend. This anomaly of about 200 gammas in magnitude is located over Triassic sandstones and shales along the line of outcrop of the upper contact of a dipping sheet of intrusive diabase. In the Harmonyville area the diabase forms the eastern end of a large basinlike sheet. The contact metamorphism of the ferruginous sediments has resulted in the development of sufficient magnetite to cause the anomaly, but not enough to be of economic significance.

Superimposed on the linear, contact-effect anomaly described above is a small, sharp, positive anomaly at Saint Peters. This oval-shaped anomaly, less than a mile long, occurs over the old French Creek iron mines. Here the ore occurred as magnetite replacement of a north-dipping limestone bed within Precambrian biotite gneiss. The gneiss also contains quartz, feldspar and graphite and is probably of sedimentary origin. The mines were opened in 1850 and operated until 1928 when the ore is reported to have been exhausted; total production was 876,000 tons. The shaft went to a depth of 1400 feet; the orebody averaged 75 feet in thickness and was mined for 1700 feet along its trend. The mineralization is believed to be of hydrothermal origin, genetically related to the nearby intrusive Triassic diabase. Associated with the magnetite mineralization was calcite, chalcopyrite, sphalerite, bornite, pyrrhotite, pyrite, and hematite. The low amplitude of the St. Peters anomaly tends to support the reports that the French Creek ore was essentially worked out.

An elongate, positive magnetic anomaly occurs south of Pughtown along French Creek in West Vincent Township. This is a low amplitude anomaly of less than 150 gammas and is probably indicative of a slight concentration of magnetite and other iron-bearing accessory minerals which have been found in the Pickering gneiss of this area. No iron concentration of economic proportions is indicated.

A small circular positive anomaly of nearly 200-gamma amplitude occurs in West Vincent Township, about a mile east of Nantmeal Village. This anomaly occurs over a topographic knob of quartz monzonite. A very small concentration of magnetite coupled with the effect of the topography readily account for this anomaly. No economic concentration of iron is indicated.

WAGONTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 223

The Wagontown quadrangle is an area underlain primarily by a variety of crystalline rocks, both metamorphic and igneous. The aeromagnetic map patterns of the quadrangle indicate that though there is not a large contrast in magnetic intensities among the different rock types, there is enough to delineate their respective distribution. A large oval area of anorthosite which makes up much of the northern half of the quadrangle is defined by a belt of small anomalies along its border. An area of gabbroic gneiss in the southwest corner of the quadrangle results in a complex positive magnetic anomaly which is a contrast to the almost featureless pattern over the granodiorite in the southeast.

A positive magnetic anomaly in Honeybrook Township, a mile west of Rockville, is the largest of a number of similar anomalies which encircle the large area of anorthosite in the northern half of the quadrangle. This anomaly has a diameter of nearly a mile and an amplitude of 350 gammas. A smaller anomaly in a similar geologic setting occurs at Brandywine Manor and three others occur south and north of Glenmore in Wallace Township. These anomalies at the margin of the anorthosite mass may be attributed to an iron silicate and iron-oxide-rich border zone reported by Bascom (1938, p. 38). The petrology of such a zone and its genetic relationship to the anorthosite make an interesting academic problem. However, neither the anomalies nor the general lithologic sequence indicate any iron concentrations of economic interest.

In the southwest corner of the quadrangle is a large, complex, positive magnetic anomaly nearly 2 miles in diameter with an amplitude of approximately 500 gammas. The anomaly actually has three separate peaks about a half mile apart. The overall anomaly occurs in an area where two large masses of gneissic gabbro and granodiorite form a complex intertonguing contact with each other. Each of the three peaks within the overall anomaly is centered over a line of contact between gabbro and granodiorite; each of these rock types has variable amounts of magnetite present as an accessory mineral, and it appears that the anomaly has formed over an area where there is a somewhat greater amount of magnetite present than is usual for these rocks. Neither the amplitude nor the sharpness of the anomaly, nor the nature of the lithologies involved, offers any encouragement as to the possibility of an economic concentration of iron ore.

A positive anomaly occurs about a mile southeast of Brandywine Manor and another about 2 miles southwest of Brandywine Manor. Each of these is a little under a mile long and has an amplitude of about 150 gammas. These anomalies are developed over gneissic granodiorite in which magnetite occurs as an accessory mineral. A small concentration of magnetite is responsible for these anomalies, but no iron concentration of minable scope is present here.

DOWNINGTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 224

The Downingtown aeromagnetic map exhibits no distinctive magnetic pattern. It is primarily an area underlain by igneous and metamorphic rocks which apparently do not have major magnetic concentrations or linear trends. Along the southern edge of the quadrangle the magnetic contour lines are few and widely spaced, denoting an area underlain by folded lower Paleozoic sediments of apparently uniformly low magnetic intensity.

A few anomalies do stand out in the crystalline area of the quadrangle. One is located along the western edge of the quadrangle, just north of the Pennsylvania Turnpike in East Nantmeal Township. The anomaly occurs over a topographic knob of quartz monzonite; the amplitude of less than 200 gammas suggests that the topography plus only a very small concentration of iron minerals are responsible. No iron concentration of economic scope is indicated.

An elongate positive anomaly occurs about a mile south of Lyndell in East Brandywine Township. The anomaly is located over crystalline granodiorite, which in this area has somewhat of a concentration of dark, iron-rich minerals including a little magnetite. This is a low amplitude anomaly of about 200 gammas and offers no encouragement for an economic concentration of iron minerals.

Several other small oval-shaped positive anomalies occur in this quadrangle. One is southeast of Anselma in West Pikeland Township; another is southeast of Lionville in Uwchlan Township; a third is just north of St. Mathews and a fourth is just north of Ludwigs Corner in West Vincent Township. Each of these positive anomalies occurs over gneissic crystalline rock which is dark colored and richer in iron minerals. These anomalies each have amplitudes of less than 200 gammas and there is no indication of concentration of iron minerals in economic quantities.

COATESVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 225

The magnetic patterns on the Coatesville aeromagnetic map in general delineate the mapped geologic units. The northern third of the map is an area of relatively few, widely spaced magnetic contours; this is an area underlain chiefly by a belt of Cambrian and Ordovician sandstones and limestones as well as a belt of the chloritic phase of the Wissahickon schist.

The southern two-thirds of the map shows numerous magnetic anomalies of different shapes and sizes, as well as a considerable variation in spacing and orientation of the magnetic contours. This area is underlain chiefly by Peters Creek schist and by the oligoclase phase of the Wissahickon schist. Intense folding in this part of the quadrangle has created complex nappe structures and fold axes with orientations which contrast with the structures to the north; the variation in structural trends is well indicated. It is interesting to note that there is no break in pattern between the Cambro-Ordovician sediments and the chloritic Wissahickon schist, even though the Martic thrust has been said to separate the two unlike lithologic units. Actually, a more distinct change in magnetic pattern occurs at the contact of the chlorite and oligoclase phases of the Wissahickon Formation.

An elongate, positive anomaly occurs in West Bradford Township, about a mile northeast of Mortonsville. The anomaly trends northeasterly, is less than a mile long, and has an amplitude of just under 150 gammas. Though that location has been mapped within the belt of chloritic Wissahickon schist, the anomaly pattern is much more like that which occurs in the adjacent Peters Creek schist or in the oligoclase phase of the Wissahickon schist. A revision of the contact may thus be in order. In any case, only a very small increase in magnetite content could cause this small anomaly and no concentration of iron in economic proportions is indicated.

In East Fallowfield Township, about a half mile southwest of Youngsburg and just south of Brandywine Creek in Newlin Township, are two positive anomalies, each less than a mile long and each with an amplitude of about 100 gammas. These anomalies occur over Peters Creek schist which in various places has been found to carry small concentrations of magnetite. Actually, the pattern of these small anomalies is very similar to that which occurs with the Wissahickon oligoclase facies and it is conceivable that structure in these crystallines places that Wissahickon unit at a shallow depth beneath these anomalies. In any case, these two anomalies offer no indication of any economic mineral concentrations.

Three elongate positive anomalies occur over oligoclase-bearing Wissahickon schist along the boundary between East Fallowfield and West Marlboro Townships. One is located a mile north of Doe Run; it is less than a mile long and has an amplitude of about 100 gammas. Another is located a half mile east of Doe Run; due to incomplete coverage of this quadrangle, the southern part of this anomaly is not closed but an amplitude of over 200 gammas is indicated. The third anomaly of this group is located 2 miles southeast of Doe Run and has an amplitude of 100 gammas. Each of these three anomalies is located over a topographic high of oligoclase-bearing Wissahickon and, on the basis of projection from a mile or two to the south, each of the anomalies is located over a structural nose which involves the Wissahickon rocks as well as the older crystalline rocks of the Baltimore gneiss. Small concentrations of magnetite are indicated, but no commercial concentration of iron minerals appears to be present.

UNIONVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 226

The Unionville quadrangle has been mapped aeromagnetically only in the northern half. The most distinctive magnetic pattern on the map consists of a series of very elongate, parallel magnetic anomalies which occur over the oligoclase-mica facies of the Wissahickon schist. The chloritic facies of the Wissahickon schist shows little or no magnetic expression, nor does the granitic gneiss or the gabbroic gneiss.

A portion of a large positive magnetic anomaly, nearly a mile wide and probably 3 miles long, appears in Newlin Township between Unionville and Marshallton. This anomaly has an amplitude of about 250 gammas and is located over a serpentinized mass within the oligoclase-bearing Wissahickon Formation. The serpentine rock of this region characteristically develops such anomalies due to the presence of small blebs of magnetite. No magnetite concentration of commercial proportions is indicated at this anomaly, either by the field evidence or by the magnetic data.

Two small positive anomalies are located a half mile north and a half mile southwest of the town of Altor in East Bradford Township. These anomalies of about 100-gamma amplitude are both located over oligoclase-bearing Wissahickon schist and are attributable to very small amounts of disseminated magnetite. No economic iron concentrations are at all indicated.

HONEY BROOK QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 233

The Honey Brook quadrangle includes a large variety of sedimentary, metamorphic and igneous rocks, all involved in complex structures. The aeromagnetic map of this quadrangle exhibits, on the whole, a single, nondistinctive magnetic pattern; there is only a subtle increase in complexity of magnetic pattern over the crystalline rocks.

Two small, positive magnetic anomalies occur in Salisbury Township, about 3 miles west of Honey Brook. Each of these anomalies is developed over a serpentine mass within an area of gneissic gabbro. These are small anomalies; each is less than a half mile in diameter and each has an amplitude of about 250 gammas. These are similar to other anomalies associated with serpentines in the Philadelphia area and are attributed to small amounts of magnetite which are commonly found with the serpentines. No iron concentration of economic scope is indicated, however.

A positive magnetic anomaly less than a mile in diameter with an amplitude of 150 gammas straddles the Lancaster-Chester County line, about a mile north of Cambridge. This occurs over an area of gneissic granodiorite with associated Pickering gneiss. This anomaly is neither large nor sharp and can be attributed to a very minor accumulation of magnetite which is common in those gneisses. No significant iron concentration is indicated.

A positive anomaly, about a half mile in diameter with an amplitude of 150 gammas, occurs about 2 miles southeast of Honey Brook. This anomaly is over the contact of a mass of quartz monzonite with granodiorite and appears to be due to a minor concentration of magnetite which has no economic possibilities.

PARKESBURG QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 234

The magnetic contour patterns of the Parkesburg quadrangle tend to reflect the major rock types of the area. A belt of anomalies at the southern edge of the map is correlated with an area of Peters Creek schist. North of that a northeast-trending belt of chloritic Wissahickon schist results in no anomalies and practically no magnetic contours on the map. Similarly, only a few simple magnetic contours are developed over the adjacent belt of lower Paleozoic limestones and sandstones which cuts across the center of the quadrangle. In the northern third of the quadrangle, an area underlain chiefly by Precambrian crystalline rocks, there are several small, low-amplitude anomalies.

A sharp, circular, positive magnetic anomaly occurs one mile north of Cochranville in West Fallowfield Township. The anomaly is only a half mile in diameter and has an amplitude of 300 gammas. It is developed over a broad area of Peters Creek schist. A shallow concentration of magnetite is indicated at this location; this is consistent with the fact that the Peters Creek Formation is known to carry disseminated magnetite. While some concentration of magnetite probably exists here, the anomaly indicates it is very limited in size, to the extent that it would not be adequate for mining purposes.

An elongate, north-south-trending positive anomaly occurs 3 miles northeast of Cochranville. The anomaly is 2 miles long, about a half mile wide, and has an amplitude of 500 gammas. The north-south trend corresponds with similar features in the adjacent Coatesville quadrangle; it is a manifestation of extremely complex folding which has developed axial trends that are unlike those farther north. The anomaly occurs over an area which is mapped as Peters Creek Formation, but the general characteristics of the anomaly are more like those associated with the oligoclase variety of the Wissahickon Formation. Inasmuch as the Peters Creek Formation rests on the Wissahickon Formation here, it may well be that the latter is the source of the anomaly; possibly it is a magnetite-bearing iron silicate zone such as has been observed elsewhere. No iron concentration of significance is indicated.

In the northeast corner of the quadrangle, a small, positive, elliptical anomaly occurs about a half mile north of Sodsburyville. This anomaly of about 150 gamma amplitude may be related to a small mass of serpentine rock which has been recognized in that area. Magnetite is commonly associated with the serpentines of this region. Neither the size nor the amplitude of the anomaly suggests anything more than a very minor concentration.

INFORMATION CIRCULAR 38. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAPS, TEMPLE, FLEETWOOD, MANATAWNY, READING, BIRDSBORO, AND BOYERTOWN QUADRANGLES

TEMPLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 227

The aeromagnetic contour patterns on the map of the Temple quadrangle show a correlation with the major structural units and rock types. In the southeast quarter of the quadrangle is part of the so-called Reading Prong; it is a complex area of crystalline rocks with infolded or infaulted Hardyston sandstone with associated large, closely spaced anomalies. The rest of the quadrangle, which is underlain by much less deformed limestones and shales of Cambrian and Ordovician age, exhibits no magnetic contour lines, an indication of uniformly low magnetic intensity.

A large, oval-shaped, positive magnetic anomaly occurs over Irish Mountain northeast of Temple in Muhlenberg Township. The anomaly is nearly two miles long and a mile wide, with an amplitude of 600 gammas. Irish Mountain is a prominent topographic feature which owes its relief to erosion-resistant Hardyston quartzite. The Hardyston Formation, not unlike the Antietam Formation farther to the south in Lancaster County, has been found in certain places to carry disseminated magnetite in the basal members. It has been suggested that this is the result of metamorphism of sedimentary hematite. The presence of a small amount of magnetite in the Hardyston at Irish Mountain, accentuated by the topographic effect, could account for the magnetic anomaly there. Neither the rock types present nor the characteristics of the anomaly offer encouragement for the possibility of an iron concentration of minable proportions.

Two small, positive magnetic anomalies occur near the eastern edge of the quadrangle along the Muhlenberg-Alsace Township line east of Temple. Each of these has an east-northeasterly trend, is less than a mile long, and has an amplitude of about 300 gammas. These occur over hornblende granite gneiss which has small but variable amounts of disseminated magnetite present. In many instances, the darker, hornblende-rich zones in the gneiss also carry more of the disseminated magnetite. At best, no more than a few percent of magnetic iron is present in these anomaly areas and neither the size nor the amplitude of the anomalies offers any indication of economically significant concentrations of iron minerals.

FLEETWOOD QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 228

The magnetic patterns on the Fleetwood quadrangle magnetic map tend to define the major rock types. The northern third of the map and the southeast corner exhibit only a few widely spaced magnetic contour lines; that is where Cambro-Ordovician limestones occur. The rest of the quadrangle exhibits closely spaced magnetic contours and numerous anomalies of various sizes and shapes; this corresponds to the area underlain by various crystalline rocks and infolded or infaulted Cambrian quartzites.

A small positive magnetic anomaly occurs about a half mile east of the town of Alsace Manor. The anomaly has an amplitude of 150 gammas. Another positive anomaly occurs at nearby Breezy Corner in Ruscombmanor Township; here, too, the amplitude is about 150 gammas and the length of the anomaly is about a half mile. A mile north of Breezy Corner an elongate positive anomaly occurs along the north flank of Sand Hill; here the anomaly has an amplitude of 500 gammas and a length of 2 miles. In the case of each of the three anomalies just cited, the underlying rock is crystalline granitic gneiss. This material locally varies considerably in composition, in places carrying small concentrations of iron-bearing minerals, including magnetite, which could readily account for these relatively small anomalies. No iron concentrations of economic importance are indicated here.

A small positive magnetic anomaly of 200-gamma amplitude occurs a half mile northeast of Pricetown in Ruscombmanor Township. Just to the east, near Seidel School, is another positive anomaly, about a half mile long with an amplitude of about 200 gammas. A mile further east, near Keller School, is another anomaly with an amplitude of 300 gammas. These three anomalies, essentially in an east-west line, are all located over granitic gneiss and are probably due to relatively minor, local concentrations of magnetite; d'Invilliers (1883) records some iron prospects here. No concentrations of economic proportions are indicated either by the extent of the anomalies or the limited occurrence of the magnetite.

Near Sheep Hill in Rockland Township is a positive anomaly about a half mile long with an amplitude of 300 gammas. An extension of this anomaly appears to trend westward for about 2 miles. Here, too, the anomaly appears to be due to a minor concentration of iron-bearing minerals in the underlying granitic gneiss; no economic potential is indicated.

An elongate positive magnetic anomaly can be traced for nearly 3 miles along the south flank of Furnace Hill near Oley Furnace. The anomaly is developed over a belt of gneiss which is rich in hornblende and which has local concentrations of magnetite. Several small mines were attempted in this zone prior to 1900: the Clymer Mine, the Tunnel Mine, the Yoder Mine and the Swoyer Mine. They encountered a layer of crystalline magnetite ore up to 5 feet thick which yielded material running as high as 59 percent metallic iron. The ore apparently occurred in the gneiss at the contact with the quartzite which makes up Furnace Hill. The anomaly suggests that some magnetite (and probably other iron minerals) still exists along the south flank of Furnace Hill, but neither the anomaly nor the relatively limited occurrence of the magnetite which has been observed offers any encouragement for a concentration here of economic proportions.

Just west of the town of Oley in the southeast corner of the quadrangle is a positive anomaly about a mile in diameter with an amplitude of 300 gammas. The anomaly straddles the contact between the old crystalline granite gneiss and the Ordovician Martinsburg shale. The form of the anomaly is characteristic of the granite gneiss and thus it appears that the gneiss extends under the shale at a shallow depth. The anomaly indicates that only a minor concentration of iron minerals exists in the gneiss; no magnetite of economic proportions is at all indicated.

MANATAWNY QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 229

The Manatawny quadrangle is underlain predominantly by old crystalline gneisses. Infolded or infaulted into these gneisses are areas of

Cambrian-age Hardyston quartzite. In each of the four corners of the quadrangle are areas of Cambro-Ordovician limestones.

The magnetic map of the Manatawny quadrangle exhibits a pattern with a number of magnetic anomalies, which in overall distribution correspond to the large area of Precambrian gneisses. The anomalies are of various sizes, shapes, amplitudes, and orientations.

The outstanding positive magnetic anomaly of the quadrangle is at Rittenhouse Gap along the eastern edge of the quadrangle. The anomaly extends onto the adjacent East Greenville quadrangle (U. S. Geological Survey Aeromagnetic Map G. P. 205). The Rittenhouse Gap anomaly has an amplitude of about 3000 gammas, one of the largest found in the entire aeromagnetic survey of southeastern Pennsylvania. During the 1870's and 1880's the Rittenhouse Gap district was the site of over 100 mines, which produced over a half million tons of magnetite ore per year. D'Invilliers (1883) gives a fairly detailed account of the major mines, their underground workings, and the nature of the ore. The Gery Mine, the Ginkinger Mine, the Rittenhouse Mine and the Miller Mine were some of the more impressive operations in this small area. Most of the mines originated as open pit operations which were then extended underground by shafts due to the steep dip of the ore zones; fairly extensive underground workings at various levels are reported. The magnetite ore zones tended to pinch and swell, attaining thicknesses of up to 30 feet. The ore zones in each case reportedly dipped about 60° to the southeast and within each band the ore tended to be concentrated in shoots pitching to the northeast. The ore was followed to depths of around 150 feet, where some of the zones pinched out. The contact between ore and country rock tends to be transitional rather than sharp; ore samples can be collected which show all degrees of concentration from nearly pure magnetite to gneiss rich in quartz, hornblende, mica, and feldspar. Several analyses of ore from the district show a range in composition as follows:

metallic iron	30-52%
sulfur	.002-1.75%
phosphorous	.006-.06%
silica	24-51%
alumina	.2-8%
magnesia	.4-9.8%

Most of the gneissic country rocks in the Rittenhouse Gap area appear to be metasedimentary, though some of the gneissic layers may have an igneous origin. The presence of pegmatites indicates igneous or near-igneous activity.

After an extensive examination of the Rittenhouse Gap area in 1918, a geologist estimated 400,000 tons of possible ore which would average

23 percent iron content. At that time the underground workings were somewhat more accessible than they are today and the report comments on the large number of lenticular ore zones as well as the gneissic country rock which invariably contains 5 percent magnetite even in the more barren zones.

Today, many of the large open cuts and pits in the Rittenhouse Gap area are still accessible, but the underground workings are partially caved and flooded.

The extent and the amplitude of the Rittenhouse Gap anomaly command serious attention. A major concentration of magnetite is indicated at a relatively shallow depth, with the ore horizon dipping to the southeast. A preliminary field examination in the area indicates that there are significant fault and fold structures which may play a role in the present distribution of the ore zones as well as in the original localization of the ore. It is noteworthy that, though the gneissic foliation strikes to the northeast, there are indications that the old mines are lined up along some type of north-south lineaments. This is an area in which further exploration, mapping, and drilling may be warranted to establish the actual size and grade of the ore zones.

A mile south of Topton, in Longswamp Township, there is a positive magnetic anomaly nearly a mile long with an amplitude of about 400 gammas. This anomaly occurs over a small area of graphitic granite gneiss which carries some magnetite. An attempt was made to mine some magnetite stringers here in the 1880's, but the mineralization was extremely thin and discontinuous. The small amplitude of the anomaly as well as the geologic nature of this rock type offer no indications of a significant iron concentration.

A small, positive anomaly a half mile west of Lower Longswamp occurs over an area of Hardyston quartzite. Though the basal Hardyston locally contains small iron concentrations, this anomaly is similar in character to those associated with the gneisses in the area; it suggests that gneiss may exist at a relatively shallow depth under the quartzite. No significant concentration of iron is indicated, however.

A northeast-trending, double-peaked, positive anomaly occurs astride the Longswamp-District Township line about a mile southwest of Rittenhouse Gap. This anomaly is over a mile long and has an amplitude of about 900 gammas. The anomaly occurs over granite gneiss and trends parallel to the gneissic foliation. This gneiss locally carries thin stringers and bands somewhat enriched in magnetite. However, the magnetic and geologic evidence at this site does not indicate commercially significant concentrations of iron.

A half mile north of Landis Store in District Township is a north-trending positive anomaly with an amplitude of over 500 gammas. This is an area of graphitic, granitic gneiss and the anomaly trends parallel to the gneissic foliation. The indications are that a band in the gneiss, somewhat enriched in magnetite, is responsible for the anomaly. Neither the rock type nor the anomaly suggests any significant concentration of magnetite.

A mile northeast of Landis Store, at the District-Hereford Township line, there is a positive magnetic anomaly of about 300 gamma amplitude. This is an area underlain by hornblende gneiss, including a small amount of disseminated magnetite. Neither the small amplitude of the anomaly nor the rock type suggests significant iron mineralization here.

A fairly large, double-peaked, positive magnetic anomaly occurs in the southeast corner of the map at the intersection of the District, Pike, and Washington Townships. The anomaly is nearly 2 miles long and occurs over an area of hornblende-rich gneiss which locally carries concentrations of disseminated magnetite. D'Invilliers (1883) reports on the Gilbert and Gilberg Mines in this area, from which titaniferous magnetite was mined in the 1880's. The mines were apparently not too successful even then. Neither the small amplitude of the anomaly nor the local geologic conditions offer any encouragement for commercially usable iron concentrations here.

A large, positive magnetic anomaly occurs a mile north of Hill Church in Pike Township. The anomaly is 2 miles long and has an amplitude of about 300 gammas. This is a broad feature of relatively low amplitude which occurs over an area of hornblende gneiss. Some disseminated accessory magnetite occurs in the rock, but the indications are that only a very minor concentration of iron exists here.

Three positive magnetic anomalies are lined up in a northeastern trend extending across Pike Township into District Township. One anomaly peak occurs just northwest of Pikeville in Pike Township; the second peak is located a mile northeast of Pikeville; the third peak occurs just west of Landis Store in District Township. These anomalies are developed over a topographic ridge made up of hornblende-bearing gneiss with some accessory titaniferous magnetite. The anomalies have amplitudes of less than 300 gammas and the indications are that there is no significant iron concentration here.

Along the western edge of the quadrangle, there is a positive magnetic anomaly north of Lobachsville, near the Rockland-Pike Township line and extending northward to Rupperts School. The underlying rock is hornblende gneiss which locally carries bands of titaniferous magnetite. These iron-rich zones are not thick enough to be mined by modern iron mining standards and the titanium content is particularly undesirable. Neither the anomaly nor the geologic conditions offer any encouragement for commercially significant iron concentrations at this locality.

A mile east-southeast of New Jerusalem in Rockland Township is an elongate, double-peaked positive anomaly. The anomaly trends eastward for a mile and a half and has an amplitude of about 300 gammas; it appears to be developed along a shear zone in hornblende gneiss (Buckwalter, 1959). Accessory magnetite is fairly common in this rock but neither the anomaly nor the local geology indicates any significant concentration here.

A mile and a half east of Dryville in Rockland Township there is a positive magnetic anomaly nearly a mile in diameter with an amplitude of about 300 gammas. The underlying rock is hornblende-rich gneiss which carries some accessory magnetite. Neither the anomaly nor the local geologic conditions indicate any economically significant iron concentration here.

A mile south of Fredericksville, along the Rockland-District Township line, there is a double-peaked positive magnetic anomaly trending northeasterly for a mile and a half. The higher, more southerly peak has an amplitude of about 500 gammas. This anomaly is underlain by a topographic ridge of hornblende gneiss and was the site of the Butler iron mine in the 1880's (d'Invilliers, 1883). The mine went to a depth of 240 feet, following a 10- to 12-foot-thick bed of granular, titaniferous magnetite in the gneiss. Within the area is a second ore bed, 3 feet thick. About 10 tons a day was mined for several years before the mine was abandoned. The pyrite, feldspar, and quartz gangue within the ore made it difficult to handle. Though the anomaly indicates that some mineralization remains here, the gangue minerals, the very high titanium content, and the relatively limited thickness all are very unfavorable conditions for modern iron mining requirements.

A mile east of Fredericksville in District Township there is a prominent positive magnetic anomaly over a half mile in diameter with an amplitude of about 400 gammas. A half mile due south is another positive anomaly of about 300-gamma amplitude. These anomalies are both over hornblende gneiss which also carries disseminated titaniferous magnetite The more southerly of these two anomalies is the site of the old Trexler Mine, which attempted to develop a titaniferous magnetite zone in the gneiss. The mine was apparently unsuccessful then (1880's) and though the anomalies suggest some iron mineralization still exists, the limited thickness of the magnetite zones, the considerable and undesirable gangue, and the highly undesirable titanium are all unfavorable for modern iron ore requirements.

READING QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 230

The Reading quadrangle is an area which involves several distinct structural and lithologic units, each of which develops its own magnetic pattern. The northwest quarter of the quadrangle shows only a couple of very widely spaced contours; this is an area underlain by Cambrian and Ordovician limestones and shales with uniformly low magnetic intensity.

The northeast corner of the quadrangle shows several pronounced, closely spaced anomalies; this is an area with considerable topographic relief, underlain by highly deformed, old crystalline gneisses of the so-called Reading Prong.

The southern part of the quadrangle is an area of Triassic sediments and igneous (diabase) dikes. The sedimentary areas develop only a few widely spaced magnetic contours due to their uniformly low magnetic intensity. The intrusive diabase, however, is responsible for a pattern of closely spaced magnetic contours running eastward across the south-central part of the map.

A large positive magnetic anomaly occurs over Mount Penn in Lower Alsace Township, just east of the city of Reading. The anomaly is over a mile long and has an amplitude of 700 gammas. The anomaly is centered over the contact between Hardyston quartzite and hornblende-granite gneiss. The Hardyston Formation, whose erosion resistance is partly responsible for the topographic expression of Mount Penn, and the hornblende-granite gneiss are both known to carry bands which are somewhat enriched in magnetite. The magnetite is disseminated and rarely extensive in size or grade. The Mount Penn anomaly is probably intensified as a result of the topographic effect of the mountain. Neither the general geologic conditions nor the nature of the anomaly offers encouragement for an important iron concentration at this locality.

About a mile south of the Mount Penn anomaly there is a curved, almost hook-shaped, positive anomaly which is developed over an unnamed ridge lying just west of Pennside along the eastern edge of the quadrangle. This is really a double-peaked anomaly; the more northerly peak has an amplitude of 250 gammas and is underlain by hornblende-granite gneiss, and the southern peak has an amplitude of 150 gammas and is underlain by Hardyston quartzite. Both of these rock units have local concentrations of magnetite in disseminated form; a relatively small amount of the mineral, accentuated in effect by the topographic relief, is probably all that is responsible for the anomaly. No economic concentration of iron is indicated by the geologic conditions or by the anomaly.

A small anomaly occurs just west of Reiffton, along the eastern edge of the quadrangle. The anomaly is about a half mile in diameter and has an amplitude of 100 gammas; it is developed over a small area of hornblende gneiss which commonly has a few percent of disseminated magnetite present. Neither the size, the amplitude, nor the rock type offers any indication of a significant amount of iron mineralization.

The magnetic contour map shows a relatively gentle, positive anomaly which extends across the southerly portion of the quadrangle from Seidel Hill on the east to a point just south of Mohnton on the west. The anomaly is developed over the outcrop of a steep, north-dipping diabase dike which has cut through Triassic sedimentary rocks just south of where they are in contact with Paleozoic limestones. There is a belt of limestone conglomerate within the Triassic shale and sandstone sequence in this area. The combination of Paleozoic limestones Triassic limestone conglomerate, and diabase intrusives makes this an area where one might consider the possibility of replacement mineral deposits within the limestones. In other areas of the Triassic belt, where such a combination of geologic formations exists, mineral deposits have been found, especially magnetite. The fact is that this area south of Reading does have a record of known mineralization. In the 1850's the Fritz Island Mine was developed in magnetite ore which was found in the Triassic limestone conglomerate as well as the adjacent Paleozoic limestone; apparently, mineralizing solutions related to the diabase introduced the magnetite as replacement material. The Fritz Island Mine was a fairly extensive underground operation with two shafts reaching a depth of nearly 280 feet and with several work levels developed. The ore lode had a dip of about 45° under the river, and a maximum thickness of 22 feet. Two hundred fifty thousand tons of ore was produced here up to 1883. There is some question whether mining was discontinued because of poor ventilation or poor ore. The aeromagnetic map does not indicate that any significant quantity of iron ore was left unmined at the Fritz Island Mine or in the immediate vicinity. Even if there were appreciable ore at Fritz Island, the sewerage plant, the general urbanization of the locality, and working under the river would prove to be virtually insurmountable problems.

A half mile west of the Fritz Island Mine the Raudenbush Mine was excavated near the contact between Triassic limestone conglomerate and diabase. It is reported (d'Invilliers, 1883) to have produced at least 5000 tons of ore per year. The ore occurred as a south-dipping vein of magnetite of variable thickness but averaged less than 12 feet. The magnetite ore solutions apparently replaced the carbonate rock. On the magnetic map a half mile east of the town of Grill (south of Reading) is a small positive magnetic anomaly which marks the site of the Raudenbush Mine. The anomaly has an amplitude of 200 gammas. The presence of the anomaly indicates some magnetite still exists there, but the small amplitude indicates that neither the grade nor the size of the mineral concentration is appreciable. From the accounts of the old Raudenbush Mine, it is questionable whether the ore zone which they then were mining would be minable on the basis of modern methods and mineral economics. Thus, the overall indications at the site of the old Raudenbush Mine, just as at the Fritz Island Mine, are that there is no economically significant iron mineralization.

It is noteworthy that Neversink Mountain, a very pronounced topographic high just southeast of Reading, shows no related magnetic anomaly. This mountain is made up of Hardyston quartzite and granite gneiss, not unlike Mount Penn and Irish Mountain, though the latter two do have associated magnetic anomalies. It is possible that Neversink Mountain may be structurally unlike the other mountains, possibly lacking a crystalline root.

BIRDSBORO QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 231

The Birdsboro quadrangle aeromagnetic map shows a few prominent magnetic anomalies which are developed over igneous and metamorphic rocks in the western half of the quadrangle. The eastern half of the quadrangle shows a very simple magnetic pattern with only a few widely spaced contour lines; this is an area underlain by Triassic sediments to the south and by Cambro-Ordovician sediments to the north.

The most prominent positive magnetic anomaly of the quadrangle occurs over Pine Ridge and Kinsey Hill in Exeter Township in the west-central part of the quadrangle. The anomaly is over 2 miles long and has an amplitude of 1000 gammas. The anomaly occurs over a thick intrusive sheet of diabase, a dense, erosion-resistant rock mass which forms Pine Ridge and Kinsey Hill. The diabase is composed in part of iron silicate minerals and also contains some accessory magnetite; the magnetic intensity of this mineral assemblage, accentuated by the topography of the ridge, may be responsible for the anomaly. However, Spencer (1908) reports that magnetite was mined at the Esterly Mine at this location 2 miles south of Jacksonwald; the ore was found at the contact between the north-dipping diabase sheet and the underlying Triassic sediments. This was not an extensive mine; only 3000 to 4000 tons of ore were reported mined. The magnetite ore apparently developed by replacement of the somewhat calcareous shales under the diabase. Within the old Esterly Mine, it is reported that the ore extended for only 100 feet in an east-west direction, but its limit down slope was not established. The shaft went down for only 125 feet. The presence of calcareous shale and the existence of limestone conglomerate only a few hundred feet away from this diabase intrusive present a relatively favorable environment for localization of any mineral solutions which might have been associated with the diabase. The 1000-gamma amplitude of the Pine Ridge-Kinsey Hill anomaly is somewhat higher than is generally found associated (300-700 gammas) with the diabase in this part of the state. This suggests that either there is a somewhat higher percentage of disseminated accessory magnetite throughout the diabase of this ridge, or else some magnetite exists as a layer or zone next to the diabase, as in the case of the Esterly Mine. In either case, the situation is not particularly encouraging; it would take relatively little additional disseminated magnetite in the diabase to account for the size of the anomaly and, similarly, a thin, relatively lean layer of magnetite next to the diabase could have the same effect. Neither of these situations would be likely to make an iron concentration of minable grade.

It is noteworthy that the Pine Ridge-Kinsey Hill anomaly is developed only over the segment of the diabase sheet which dips north; where the diabase swings around and dips southward (opposite to the natural plunge of the earth's magnetic lines at this part of the world) the magnetic map shows very little magnetic effect. It may also be observed that an adjacent parallel sheet of extrusive basalt, presumably genetically related to the diabase, shows no manifestations on the magnetic map over either its north- or south-dipping segments.

In the southwestern corner of the quadrangle, elongate positive magnetic anomalies are developed over Sheep Hill and Cedar Hill; these ridges are topographic expressions of a continuous, steep, north-dipping diabase sheet which extends onto the adjacent quadrangles. These anomalies have amplitudes of about 700 gammas. The diabase contains some disseminated magnetite as well as numerous iron silicate minerals; the field and map evidence indicates that the magnetic effect of these minerals, accentuated by the topography, is responsible for these anomalies. Neither the geologic data nor the magnetic data suggest any economically significant iron concentration here.

In the northwest corner of the quadrangle, a positive magnetic anomaly occurs in Alsace Township, about a mile north of Antietam Reservoir. The anomaly trends northeasterly, is about a mile long, and has an amplitude of about 300 gammas. The anomaly is developed over a mass of granitic gneiss which forms a topographic high. This rock type is widespread in the area and quite variable in composition; locally it shows concentration of hornblende as well as disseminated magnetite. Such a mineral assemblage, coupled with the topographic effect, can readily account for this relatively small anomaly. No significant concentration of iron is indicated here.

A prominent positive magnetic anomaly occurs along the northern edge of the quadrangle, just east of Spies Church in Alsace Township. The anomaly is only about a half mile in diameter but has an amplitude of over 1000 gammas. The anomaly occurs over the flank of a knob made up of dark, hornblende-rich gneiss which is surrounded by lighter colored, granitic gneiss. Field examination to date has revealed extremely little accessory magnetite in the rocks at the surface; the anomaly suggests a more pronounced concentration of magnetite at a shallow depth, though it is impossible to figure the actual degree of concentration. It would require more exploratory work, possibly including some drilling, to fully assess the origin of this anomaly. The limited diameter of the anomaly tends to be a discouraging factor as far as the potentiality of large size or tonnage of the source material is concerned.

A positive magnetic anomaly occurs in Exeter Township, a half mile west of Oley Line; the anomaly trends in a north-northeasterly direction, is about a mile long, and has an amplitude of 200 gammas. This anomaly is developed over a low hill of granitic gneiss. The gneiss exhibits considerable variation in mineral content and locally has concentrations of hornblende and small amounts of disseminated magnetite; such a situation, accentuated by the topography, readily accounts for this anomaly. No economic concentration of iron is indicated here.

BOYERTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 232

The variation of magnetic patterns on the Boyertown magnetic map shows a marked correlation with the major rock types. The northern half of the quadrangle exhibits numerous magnetic anomalies of various sizes, shapes, and orientations; this is an area underlain by old crystalline gneisses with some infolded and infaulted areas of Cambrian quartzite.

The southern half of the quadrangle exhibits few, widely spaced magnetic contours; this area is underlain by Triassic sandstones and shales.

The Triassic igneous rocks and associated mineralization are well defined by the prominent magnetic pattern in the east-central portion of the map.

Along the northern edge of the quadrangle, 2 miles west of Bechtelsville, are two positive magnetic anomalies, one just southwest of the other. These anomalies are each about a half mile in diameter with an amplitude of approximately 400 gammas. The underlying rock is granitic gneiss which locally carries small concentrations of disseminated magnetite.

The northeast-southwest orientation of these two anomalies is parallel to the trend of the foliation and suggests the presence of a layer with some magnetite. However, neither the amplitude of the anomalies nor the lithologic character of these rocks offers encouragement for the presence of significant amounts of iron here.

A pronounced positive magnetic anomaly trends southwest from Bechtelsville for nearly 5 miles. Near Bechtelsville, it is about a half mile wide, but at its southwestern end (near Long Hill) it broadens out to a mile in width and an amplitude of 800 gammas. Along its entire length this anomaly occurs over hornblende-bearing gneiss which also carries some disseminated magnetite. It is noteworthy that this magnetic feature not only parallels the trend of the gneissic foliation, but it is parallel to (and on the south side of) a major fault zone. The southwestern end of this anomaly is parallel to Long Hill, a ridge held up by downfaulted, erosion-resistant Hardyston quartzite. The northwest-trending cross-faults, which mark the southwest and northeast ends of the Long Hill quartzite, also mark the southwest end of the anomaly as well as the point further to the northeast where the anomaly abruptly becomes narrower. These relationships indicate that the zone which is responsible for the anomaly has been involved in the Paleozoic structural deformation of the area. Though this is a pronounced anomaly indicating a zone which must have some concentration of iron, probably in the form of magnetite, it is unlikely that this anomaly of less than 1000-gamma amplitude in a crystalline environment is due to anything more than a band of relatively lean, disseminated magnetite. The anomaly probably defines a feature of structural and petrographic interest rather than one of economic significance.

A positive magnetic anomaly occurs in the northwest portion of the quadrangle between Stone Cave Hill and Saenger Hill in Earl Township. This magnetic feature trends north and manifests peaks near Woodchoppertown, Furnace Hill, and Shenkel Hill. The trend of this complex magnetic feature corresponds with the basal contact between a north-trending belt of Hardyston quartzite and the adjacent hornblende-bearing gneiss; even the offsets of the contact due to cross-faults are reflected by the magnetic feature. The maximum amplitude of 300 gammas virtually eliminates the possibility of any commercial concentrations of iron ore but the origin of this magnetic anomaly is a matter of academic interest. The phenomenon of a positive magnetic anomaly along the Hardyston-gneiss contact occurs at several localities in the Reading Prong area. While the gneiss may be observed to carry magnetite many places in this region, the repeated occurrence of magnetic anomalies along Hardyston quartzite-gneiss contact suggests the possibility of a zone of magnetite in the basal conglomerate of the Hardyston quartzite. In none of these situations, however, is a concentration of commercial scope indicated.

In the east-central part of the Boyertown magnetic map a pronounced magnetic feature may be observed over Boyertown and extending south and southeast toward Upper Pottsgrove. The portion of the positive anomaly about a half mile wide extending south and southeast from the Colebrookdale-Douglass Township line is developed over the outcrop belt of a northeast-dipping sheet of diabase which has intruded the Triassic sediments. The diabase and the anomaly extend onto the adjacent Sassamansville quadrangle. The diabase is partly composed of iron silicate minerals as well as some disseminated magnetite. The 500-gamma amplitude of this anomaly over the diabase is within the range commonly found over other diabase masses in this part of the state. Though some relatively minor contact metamorphic effects are noted along the contact between the diabase and the Triassic sandstones and shales, the anomaly along the Marysville-Colebrookdale-Cedar Grove belt can be attributed primarily to the diabase, with no indications of economic iron concentrations.

At the southern edge of the city of Boyertown is the center of a broad, nearly circular positive magnetic anomaly; this anomaly appears on the magnetic map to be connected to the northern end of the linear anomaly attributable to the diabase. The diameter of the circular anomaly is about a mile and a half; the amplitude is a little over 500 gammas. The circular Boyertown anomaly occurs at the site of the old Boyertown mines. Spencer (1908) and d'Invilliers (1883) give extensive descriptions of the complex workings involving five orebodies clustered together at Boyertown. An extensive network of shafts and tunnels existed here in the 1880's; a maximum depth of over 660 feet was achieved in the mining. Though the surface rock in Boyertown is Triassic sediments, the ore was found as replacements of Paleozoic limestone which underlies the Triassic rocks; the Triassic-Paleozoic contact dips southeast at Boyertown and the ore horizons beneath the Triassic also dipped southeast. It has been variously suggested that the five orebodies may be interconnected at depth or that they may be segments of one original ore horizon which was offset by faulting. The ore horizons at Boyertown, while essentially tabular or lenticular, tended to pinch and swell, reaching a maximum thickness of 40 feet.

The geologic conditions in the Boyertown area were extremely favorable for the localization of ore deposits. The upper Triassic diabase intrusives came into close proximity with Paleozoic limestones as well as Triassic limestone breccias; thus, carbonate host rocks were available for replacement by ore solutions.

The history of successful mining, as well as the fairly extensive belt of favorable geologic conditions, has brought about renewed interest in the possibilities of the Boyertown area. In 1916-1917 the Boyertown Ore Company did some dewatering of the old mines and put down four drill holes; one vertical hole encountered 13 feet of ore at a depth of 954 feet. In 1943-1944 the U. S. Geological Survey and the U. S. Bureau of Mines engaged in geologic and magnetic surveys around Boyertown; the U. S. Defense Plant Corporation put down two drill holes. Hawkes (1953) reports one vertical drill hole encountered 23 feet of ore at a depth of 612 feet, which would average about 16 percent removable iron. The second vertical hole encountered 33 feet of ore at a depth of 1170 feet, which would average about 23 percent removable iron.

Ground magnetic surveys in Boyertown city limits were rendered essentially useless by the magnetic effects of buildings and man-made features. The airborne magnetometer survey of 1944 indicated the locations of the old mines in Boyertown, particularly the Gabel and Warwick Mines. Northeast of Boyertown, however, the ground magnetic surveys indicated two possible small orebodies about 5000 feet northeast of New Berlinville, near the site of the old Fegley Mine (Sassamansville quadrangle). Southwest of Boyertown the 1944 ground magnetics indicated a possible small orebody along the edge of the diabase 1500 feet southwest of the old Boyertown mines; the old Brower Mine 3000 feet southwest of Boyertown also showed a small amount of ore remaining.

The geologic, magnetic, and drilling data at Boyertown show some iron mineralization still exists there; the problem is how rich is it and how large. The old drilling data cited above are not encouraging as to continuity and grade of the ore zones at Boyertown. The 500-gamma anomaly on the new magnetic map (G.P. 232) is also not very encouraging for an iron mine here. It is of considerable academic interest, however, that the anomaly at Boyertown is so broad, extending eastward over the Triassic rocks and westward across the Paleozoics and on over the crystallines for a half mile; this suggests the possibility of some large structural unit.

Along the southern edge of the Boyertown quadrangle, about a mile west of Stowe, a broad, gentle, positive anomaly occurs. This magnetic feature is underlain by a mass of diabase whose iron-bearing minerals readily account for the anomaly. Neither the rock type nor the 100-gamma anomaly indicates any significant iron mineralization.

INFORMATION CIRCULAR 39. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAPS, EASTON AND RIEGELSVILLE QUADRANGLES

EASTON QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 235

Only the western half of the Easton quadrangle, that portion west of the Delaware River, has been covered by this aeromagnetic survey. The magnetic patterns exhibit a marked distinction between the areas of crystalline rocks and those of sedimentary rocks. The crystalline areas exhibit numerous anomalies of various size, shape and orientation. The sedimentary belts, as at the city of Easton and in the northern third of the quadrangle, show relatively low, uniform magnetic fields.

An elongate, northeast-trending positive magnetic anomaly, just north of the city of Easton, is underlain by a belt of gneiss and serpentinized Franklin marble. Both of these rock units contain conspicuous quantities of disseminated magnetite as well as other iron silicate minerals. The anomaly has an amplitude of 1000 gammas, but this is an amplitude accentuated by marked contrast with adjacent lithologies and structures; no iron concentration of mining proportion is indicated at this location.

A number of anomalies occur over the crystallines in the southern half of the area mapped. One is centered over Morgan Hill, two miles south of Easton, another occurs southeast of Fairview School, and a third is found over Elephant Rock. Each of the anomalies in the gneissic area is located over a topographic high and, in turn, the topographic high appears to be related to the local composition of the rock. Various authors have ascribed different names to the gneisses of the area, but in each case the rock under the anomaly is darker and richer in iron minerals, including magnetite, than the rocks in the rest of the area. Coarse disseminated magnetite can be observed in the field; at Morgan Hill, where the anomaly has an amplitude of 800 gammas, an ill-fated attempt was once made to mine the material.

The anomalies appear to be the composite result of the disseminated magnetite and the topography. There does not appear to be any indication of a magnetite concentration which has economic mining possibilities.

RIEGELSVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 236

Only the portion of the Riegelsville quadrangle west of the Delaware River has been covered by this aeromagnetic survey. There is a distinct correlation between the magnetic patterns and the type of underlying rock. In the southern part of the quadrangle, the magnetic contours are simple and widely spaced; that is an area underlain by a thick sequence of Triassic sandstones and shales. In the Coffeetown area, in the northern part of the quadrangle, a large negative anomaly is developed over a northeast-trending belt of Cambrian limestones. The rest of the quadrangle exhibits a number of anomalies of various sizes, shapes and orientations; this involves an area underlain by a complex of crystalline rocks.

A positive magnetic anomaly occurs over Rattlesnake Hill near Durham Furnace in Durham Township. The anomaly is less than a mile long and has an amplitude of nearly 300 gammas. Rattlesnake Hill and nearby Mine Hill were the site of a number of small iron mines which supplied magnetite and hematite ore to Durham Furnace intermittently from 1700 to 1908. Bayley (1941) reports the ore occurred as a number of lenses and pods within the gneissic country rock. Dimensions varied greatly from orebody to orebody, and even within individual orebodies; maximum reported width was 50 feet, length 500 feet, and height 40 feet. The ore contained about 50 percent iron content and quartz was the chief gangue; some barite is also present but it is believed to have been introduced in Triassic time. The general geological setting and nature of the ore are similar to those of the larger and better known iron operations in the crystalline rocks of New Jersey. The anomaly over Rattlesnake Hill indicates that some magnetite remains, but the small size and amplitude suggest that the iron concentration is too small in size and too low in grade to warrant economic development. It is noteworthy that Mine Hill, which was the site of considerable mining at the time of Rattlesnake Hill activity, shows no related anomaly. This is attributable to the predominance of nonmagnetic hematite, rather than magnetite, at Mine Hill.

A positive anomaly is centered over Monroe in Durham Township. It trends northeasterly, and has a length of over a mile and an amplitude of over 150 gammas. The anomaly occurs where Triassic limestone conglomerate is in fault contact with Precambrian gneisses, Cambrian sandstones, and a sliver of Cambrian limestone. The limestones present offer an ideal host rock for mineralizing solutions, and it is noteworthy that this is an area where barite mineralization of Triassic age is reported. The anomaly suggests a mineralized zone which could be either a magnetite-bearing zone in underlying gneiss or else the result of magnetite mineralization along the fault. If the anomaly were larger and more intense, the situation would be interesting and worthy of further research. The fault zone may have served as a channel for mineralizing solutions related to the Triassic diabase intrusion which formed just a couple of miles to the south.

A small anomaly lies southwest of the Monroe anomaly described above and is apparently of the same origin. Being less than a half mile in diameter with an amplitude of only 100 gammas, it has no economic potential.

INFORMATION CIRCULAR 40. GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAPS, HATBORO AND LANGHORNE QUADRANGLES

HATBORO QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 237

The aeromagnetic contour map of the Hatboro quadrangle exhibits two contrasting magnetic patterns. The northern half of the map has very few contour lines with no distinctive trend; this area of uniform magnetic intensity is underlain by Triassic sandstones and shales. The southern portion of the map shows some pronounced, elongate magnetic anomalies; these occur over an area of crystalline rocks, mostly gneisses.

A large positive magnetic anomaly occurs in Lower Moreland and Upper Southampton Townships. This elongate anomaly trends in a northeasterly direction, and is at least 3 miles long and a mile wide. The amplitude is on the order of 750 gammas. The anomaly coincides with an area of dark amphibolite gneiss which occurs within a larger area of light-colored granitic Baltimore gneiss. The amphibolite gneiss is rich in iron silicates as well as disseminated magnetite; the areal extent as well as the amplitude of the anomaly indicates that this zone of iron-bearing minerals has considerable depth as well as lateral extent. It is noteworthy that the northeasterly trend of this zone is in discordance with the easterly trend of the structures developed in the nearby Paleozoic sediments during the Appalachian orogeny. Despite the extent and amplitude of the anomaly, it does not appear likely that an iron concentration of economic scope is present here. Surface exposures show magnetite, but only as disseminated grains in the dark gneiss; these alone are probably responsible for the anomaly.

In the southeast corner of the quadrangle, over the town of Feasterville in Lower Southampton Township, there is a large positive magnetic anomaly of the same nature and origin as the one described above. The Feasterville anomaly also trends northeasterly (extending onto the adjacent Langhorne quadrangle) for about 3 miles, has a width of over a mile, and has an amplitude of about 900 gammas. The origin of this anomaly appears to be a mass of magnetite-bearing hornblende gneiss. The magnitude of the anomaly indicates that this is a major lithologic and structural unit. However, surface sampling does not indicate an iron concentration of economic importance. The urban nature of this area precludes any mining development even if significant mineralization were to exist.

LANGHORNE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 238

The aeromagnetic contour pattern in the Langhorne quadrangle is controlled chiefly by lithologic (rock) units within the older crystalline basement rocks. This is so even where the basement rocks are covered, as in the northern half of the quadrangle where Triassic sediments occur at the surface, and in the very southern part of the quadrangle where young, unconsolidated sediments rest on the crystalline rocks. The anomalies are sharpest in a belt trending northeasterly across the center of the quadrangle, where the crystalline rocks are actually exposed at the surface.

In the southwestern corner of the quadrangle in the vicinity of Trevose Heights, there is the continuation of a northeast-trending positive magnetic anomaly, the peak of which is actually on the adjacent Hatboro quadrangle. This anomaly corresponds with an area of dark amphibolite gneiss surrounded by light-colored granitic gneiss. The amphibolite gneiss contains iron silicate minerals as well as disseminated magnetite, the latter being largely the cause of the anomaly. There appear to be only sparse grains of magnetite and neither the rock nor the anomaly offers encouragement for economically significant concentrations of iron ore. The northeasterly trend of the anomaly and the causative zone in the crystalline rocks are in contrast to the more easterly trends developed by the Appalachian deformation at a later date.

A northeast-trending, elongate positive anomaly occurs east of Langhorne in Middletown Township. This feature has a length of nearly 2 miles and an amplitude of 500 gammas. The source of this anomaly is similar to the one described above, namely, a mass of magnetite-bearing amphibolite gneiss within a large area of granitic gneiss. Here, too, the disseminated occurrence of the magnetite, as well as the urban nature of the area, precludes any iron concentration of economic potential.

In the southeast corner of the quadrangle there is hook-shaped, elongate positive anomaly in the area of Hulmeyville. The anomaly has an amplitude of 250 gammas and is a few miles in length. This is an area of crystalline rocks overlain by young, unconsolidated sands and gravels. In the stream valleys, however, the overburden has been worked away and the crystalline rocks can be seen. The anomaly area corresponds in part with areas of dark amphibolite gneiss which are found in places within the crystalline Wissahickon Formation. Disseminated magnetite is found in the dark gneiss and the anomaly probably defines a deformed mass of such material. Neither the surface geology nor the details of the anomaly indicate an economic concentration of iron ore.

In the northerly portion of the quadrangle, there is a large, northeast-trending anomaly which includes the area of Newtown. The anomaly is not outstanding on the map due to its small amplitude (only 100 gammas) and its large area. This is an area of Triassic sediments, but the anomaly is probably due to a zone of magnetite-bearing amphibolite gneiss in the crystalline gneiss beneath the Triassic sediments. The anomaly appears to be the northeasterly extension of a similar feature which appears in the adjacent Hatboro quadrangle where dark gneiss is actually exposed on the surface. No significant concentration of iron is indicated in either case.

INFORMATION CIRCULAR 41. GEOLOGIC INTERPRETATION OF CERTAIN AEROMAGNETIC MAPS OF LANCASTER, BERKS, AND LEBANON COUNTIES

WOMELSDORF QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 239

The Womelsdorf quadrangle aeromagnetic map is dominated by a broad magnetic high which is centered near the junction of Lebanon, Lancaster, and Berks Counties. This is the center of a topographic high known as South Mountain, a more or less oval area made up of Precambrian granitic gneiss with lesser amounts of hornblende gneiss. Such rock units are typically characterized by sharp magnetic highs. These crystallines are overlapped on the north and northwest by Hardyston quartzite and successively younger limestones of Cambrian age. To the south, the South Mountain crystallines are in fault contact with Triassic sediments. The sedimentary units in the quadrangle have little magnetic variation and low intensity.

The magnetic high over the South Mountain crystallines has an amplitude of only 200 gammas. This is unusually small for a crystalline mass which is in such marked petrographic and topographic contrast to the adjacent sediments. Such a small anomaly is interpreted to signify that the crystalline mass is relatively thin, and is part of a rootless thrust sheet. This interpretation has been incorporated in the 1960 edition of the Geologic Map of Pennsylvania. No mineralization of economic significance is magnetically indicated in the Womelsdorf quadrangle.

SINKING SPRING QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 240

Although the magnetic pattern on the Sinking Spring map shows considerable variation, a direct correlation can be established between the known lithologies and the magnetic features.

The northern half of the quadrangle has only a few widely spaced magnetic contours. This is an area of Ordovician limestones and shales of uniform, low magnetic intensity.

A magnetic high occurs in the southeastern part of the quadrangle in Spring Township, about a mile northwest of Gouglersville. The anomaly has an amplitude of about 400 gammas. It is located over a Triassic diabase dike; the ferromagnesian minerals plus the accessory magnetite in the diabase appear to be responsible for this anomaly. No economically significant iron mineralization is indicated, however.

There are two magnetic highs of low amplitude in the west-central part of the quadrangle. One is centered over Cushion Peak west of Fritztown; the other is located west of Highland in South Heidelberg Township. The Cushion Peak area is one where a veneer of Hardyston quartzite lies on Precambrian granitic gneiss. The South Heidelberg anomaly is directly underlain by gneiss. The iron-bearing minerals of the gneiss tend to produce magnetic highs in contrast to the adjacent sedimentary rocks. The small area and amplitude of the anomalies, and the mineral composition of the gneiss, indicate there is no iron concentration of economic interest at these locations.

EPHRATA QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 241

The Ephrata quadrangle aeromagnetic map denotes an area of very minor magnetic variation. This is an area consisting of Cambro-Ordovician shales and limestones and a downfaulted wedge of Triassic shales and sandstones. There is considerable faulting in the area, as well as some folding, but the considerable thicknesses and relatively uniform magnetic intensities of these units do not permit them to reflect the structures on the magnetic map. There are no distinctive anomalies and no magnetic mineralization is indicated.

TERRE HILL QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 242

The Terre Hill quadrangle aeromagnetic map shows a sizable positive magnetic anomaly in Brecknock Township in the northeast portion of the quadrangle. The anomaly, with a relief of over 500 gammas, is developed directly over a mass of intrusive Triassic diabase. The shape of the anomaly corresponds to the outcrop area of the diabase. The anomaly is apparently a result of the ferruginous minerals and accessory magnetite in the diabase, accentuated by the considerable thickness of the igneous intrusive. There has also been a small amount of contact metamorphism effected in the ferruginous Triassic sediments. However, no economically significant mineralization is indicated in either the diabase or the sediments.

The other sections of the quadrangle exhibit very little magnetic relief, being underlain by considerable thicknesses of Cambro-Ordovician limestones, dolomites, and shales, as well as Triassic sandstones and shales. The magnetic map does not indicate any outstanding structural or mineralogical variations within these units.

LEOLA QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 243

The Leola quadrangle map has a very simple pattern with widely spaced magnetic contour lines. This is an area of Cambrian and Ordovician limestones and dolomites which have been considerably folded and faulted. These sediments are thick here and of relatively uniform magnetic intensity, so that the structure is not indicated by the magnetic pattern. No magnetic anomalies are present on the map and no magnetic mineralization is indicated.

NEW HOLLAND QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 244

The New Holland quadrangle aeromagnetic map is dominated by a positive magnetic anomaly in East Earl Township in the east central section of the quadrangle. The anomaly has an amplitude of nearly 300 gammas, is oval in shape, and has a diameter of nearly two miles. This magnetic feature is located over a ridge of Chickies quartzite. However, it appears from the magnetic pattern that the anomaly source is fairly deep seated, probably the subsurface extension of a mass of gabbroic gneiss which is exposed a few miles to the east where it is the apparent source of two small magnetic highs. The gabbroic gneiss, much of which may be metasedimentary, is exposed in the New Holland quadrangle just southwest of Mount Airy, where it forms a small, secondary magnetic high at the edge of the larger one described above. No economic concentration of magnetic material is indicated in this area, nor elsewhere in the New Holland quadrangle. The rest of the quadrangle has only a small magnetic variation, being underlain by a folded and faulted sequence of Cambrian limestones, dolomites, quartzite, schist, and phyllite. They apparently have fairly uniform magnetic intensities, inasmuch as the magnetic map pattern does not reflect the structures present.

GAP QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 245

The Gap quadrangle aeromagnetic map shows a diversity of patterns which can be correlated with the variety of lithologies which have been mapped in the area.

The northern edge of the quadrangle has a very few, widely spaced magnetic lines. This is an area of Cambro-Ordovician limestones, dolomites, phyllite, and quartzite which have uniform, low magnetic intensities.

The southern third of the quadrangle shows a pattern of closely spaced, northeast-trending magnetic lines. This section is underlain by albite-chlorite-bearing Wissahickon schist, as well as by a synclinal belt of Peters Creek sericite-quartz schist in the southeast corner of the quadrangle. The Peters Creek area forms a magnetic low compared with the pattern over the belt of Wissahickon schist. The Wissahickon schist contains minor amounts of iron silicate minerals, as well as very small quantities of magnetite. Such positive magnetic anomalies as occur in Bart Township, a mile north of Bartville, and two miles northeast of Bartville, signify only very minor concentrations of iron-bearing minerals which have no economic significance.

In the central portion of the quadrangle there is a northeast-trending belt which exhibits relatively little magnetic variation, yet shows several separate magnetic highs. This is a belt of complex lithology. A mass of granitic Baltimore gneiss that forms the core of the Mine Ridge anticlinorium is overlapped on the flanks by a belt of Chickies quartzite. Within the gneiss there are intrusions of quartz monzonite, serpentinite, and metagabbro.

In Bart Township the margin of the metagabbro, or norite, was mined for its nickel content from 1862 to 1893, at which time competition with higher grade foreign ores put it out of business. The ore mineral in the norite is pentlandite (a sulfide of iron and nickel) and the general geologic setting is very similar to that of the Sudbury (Canada) nickel deposit. The Gap nickel ore ranged from 1 to 3 percent nickel content (Knopf and Jonas, 1929) and was smelted at the site. The aeromagnetic map shows a small magnetic anomaly at the site of the old nickel mine, with a rather meager amplitude of about 50 gammas.

In Paradise Township, about a half mile north of the Gap nickel mine site, the magnetic map shows a distinct positive anomaly. It has an east-west trend, is about a half mile long, and has an amplitude of nearly 200 gammas. This is a challenging feature, for it is developed over gently dipping Chickies Quartzite whose mineralogy offers no logical anomaly source. The Chickies here is not very thick and it is directly underlain by the crystalline core of the Mine Ridge anticlinorium. It would seem likely that the anomaly is related to one of the relatively iron-rich lithologies which have intruded the granitic gneiss, such as serpentinite or metagabbro. The proximity of Gap nickel-bearing metagabbro makes the anomaly all the more intriguing, particularly since the pyrrhotite-pentlandite mineralogy is slightly magnetic. It must be cautioned, however, that a body of metagabbro could be non-ore-bearing and still have enough ferruginous minerals to account for the anomaly. Similarly, in other parts of southeast Pennsylvania it has been found that intrusive serpentinites have small quantities of disseminated magnetite which are responsible for magnetic highs, though of no commercial significance; this is therefore another possible explanation for the source of this magnetic anomaly.

A small magnetic high is located a mile southwest of Coopersville in Sadsbury Township. This feature is developed over a narrow belt of steeply dipping Chickies, Antietam, and Harpers Formations. The latter two have been found to contain small amounts of disseminated magnetite grains in other parts of Lancaster County. A similar magnetic source is indicated here, although neither the size nor the amplitude of the anomaly indicates a significant or commercial concentration of iron mineralization.

LEBANON AND RICHLAND QUADRANGLES

U. S. Geological Survey Aeromagnetic Maps G. P. 254 and G. P. 255

The Lebanon and Richland aeromagnetic maps are of particular interest inasmuch as they include Cornwall, one of the two large iron-mining operations in Pennsylvania (Gray and Lapham, 1961).

The northern two-thirds of these quadrangles, underlain by Cambro-Ordovician limestones, shale, and dolomites, shows essentially no magnetic relief, except for a few small anomalies which are related to industrial plants in the city of Lebanon.

In the southern part of the area, Triassic sediments and intrusive diabase are in contact with the Cambro-Ordovician sediments. Here the magnetic map shows considerable magnetic variation due to the presence of the diabase and the magnetite orebodies. The magnetic anomalies over the known orebodies are not strikingly different from some of the anomalies over diabase which are known to be barren on the basis of exploration drilling. Thus there remains the question as to whether certain of the other untested anomalies can be attributed to diabase or to heretofore unknown orebodies.

The anomalies of known source will be considered first. A quarter mile directly south of Burd Coleman Village, an anomaly occurs over the western half of the more westerly of the two developed iron orebodies at Cornwall (Figure 2, anomaly 3). This is an underground operation today, although it was originally developed as an open pit mine in 1742. The ore mineral is magnetite and the ore grade as mined is about 42 percent iron content. Chalcopyrite yields some byproduct copper, gold, and silver, while the pyrite yields some byproduct cobalt. The ore was formed by replacement of the Cambrian limestone by hydrothermal solutions which were genetically related to Triassic diabase that cuts the limestone in the Cornwall area. Although this western orebody at Cornwall has been in production over 200 years, there are still quite a few million tons of ore remaining. It is of considerable interest that such a quantity of magnetite ore has resulted in a magnetic anomaly of less than 300-gamma amplitude and is limited to the western half of the orebody.

A half mile southeast of Cornwall Furnace there is a magnetic high (Figure 2, anomaly 5) with an amplitude of about 300 gammas which is developed over the more easterly of the two magnetite orebodies being mined at Cornwall. This is an underground operation. Here, too, the magnetite ore has replaced Paleozoic limestone which was overlain by Triassic sediments and underlain by Triassic diabase. As in the case of the more westerly orebody described above, this is a surprisingly small magnetic anomaly for an orebody with many millions of tons of magne-

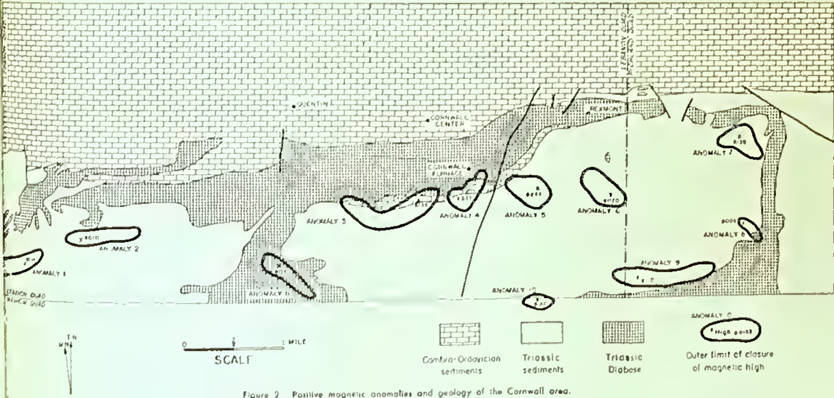

Figure 9 Positive magnetic anomalies and geology of the Cornwall area.

tite remaining. A possible explanation may be that oriented ore specimens taken from the underground workings here have been found to have a remnant magnetization which plunges to the west at nearly 90 degrees from the present direction of the earth's magnetic lines of force. As a result, the earth's magnetic field partially counteracts the measured magnetic intensity of the orebody. It is difficult to assign an explanation for such a magnetic orientation in the ore, but its practical significance is that, in this area, a geologic explanation should be sought for each anomaly, since a relatively insignificant anomaly might represent an orebody of significant dimensions.

A mile due south of Rexmont there is a magnetic high (Figure 2, anomaly 6) with an amplitude of about 150 gammas. On the surface this is an area of Triassic sediments, but nearby there is a small area of diabase exposed, suggesting that this anomaly is over an area where there is very likely a considerable mass of diabase just a short distance beneath the surface. Although it can be inferred that this magnetic high is attributable to diabase alone, a ferruginous mineral concentration within, adjacent to, or below the diabase is also possible. In this region of known magnetite mineralization no such anomaly should be overlooked in any comprehensive exploration program.

Due south of Cornwall Furnace, near Miners Village, there is a distinct magnetic high (Figure 2, anomaly 4) about a half mile in diameter with an amplitude of over 400 gammas. This magnetic feature exhibits the greatest amplitude and highest magnetic intensity of any in the Cornwall district; however, it lies only in part over the eastern edge of the western orebody. Nevertheless, it strongly indicates a significant mass of iron ore. The anomaly gradient and outline suggest a well-defined, steeply dipping iron concentration at no very great depth. The proximity of this feature to the extensive westernmost Cornwall orebody is encouraging and offers the possibility of a new ore extension which genetically might have been the feeder pipe extending upward through the diabase to the known westernmost orebody.

About two miles east of Rexmont, and just east of the small Lebanon reservoir in the Richland quadrangle, there is a magnetic high (Figure 2, anomaly 7) about a half mile in diameter with an amplitude of over 250 gammas. This feature is directly underlain by Triassic shales, although the indications are that the diabase dike, which is exposed just to the north and east, dips under the sediments in the area of this anomaly. This is not a location of known iron mineralization. Examination of the surface rocks shows some contact metamorphic effects, such as darkening and induration of the normally red Triassic sediments. No ore mineralization is exposed. The magnetic anomaly which has a peak as high as the one over the westernmost operating Cornwall orebody may indicate a significant iron concentration either over, in, or below the diabase which dips below this location. One cannot establish the nature of the mineralization without core-drilling, but the structure of this particular location shows an unusual similarity to that which exists at the known Cornwall orebodies just a couple of miles to the west. If, beneath the surface, there were a limestone mass in proximity to the diabase, it could have readily lent itself to ore replacement. Anomaly 7 (Figure 2) is one that strongly recommends itself to exploration for ore possibilities.

In the southwestern portion of the Richland quadrangle, about a mile south-southeast of the small Lebanon reservoir, there is a magnetic high (Figure 2, anomaly 8) developed over the contact of Triassic diabase and sandstone. This anomaly might be considered in conjunction with the magnetic high in the very southwest corner of the quadrangle (anomaly 9) as well as anomaly 10 which is in the southeast corner of the Lebanon quadrangle. These appear to be spatially related and probably have a common origin. The magnetic highs are not developed directly over the exposed diabase dike, but are located down the dip of the diabase. No mineralization has been noted at the surface. Since these anomalies have a lesser magnitude than those over the known orebodies, and since they are nearly two miles south of the contact between the Triassic sandstones and the lower Paleozoic limestones, the likelihood of significant iron ore mineralization here appears to be quite small. These magnetic highs may be the result of contact effects over the steeply dipping diabase, since metamorphism of the ferruginous Triassic sandstones has in many places been found to develop disseminated, fine-grained magnetite. These anomalies might also be the result of an iron-rich mineral concentration within the diabase. While the geologic and geophysical indications here (at anomalies 8 and 9) are not particularly encouraging with respect to economic iron concentrations, it would seem that any anomalous situation which is less than four miles from major iron ore concentrations merits further investigation.

A mile and a half south of Quentin in the Lebanon quadrangle there is a magnetic high (Figure 2, anomaly 11) centered over Triassic diabase. This intrusive mass is considered to be part of a basin-shaped sheet, but it is possible that the anomaly is developed over a feeder pipe of the diabase mass. The existence of a feeder pipe is suggested partly by the fact that nowhere else in the Cornwall area does the diabase exhibit an anomaly over its outcrop belt and partly by the location of this anomaly with respect to the general configuration of the diabase mass. As noted above, it is possible that this anomaly also could be the result of an iron-rich concentration within the diabase. While the magnetic intensity is not as high as that which occurs over the known orebodies, this is an area where perceptible anomalies merit consideration.

In the southwest corner of the Lebanon quadrangle, two magnetic highs occur in West Cornwall Township, about a mile northwest of Mount Gretna Heights. These peaks (anomalies 1 and 2) occur along a continuous magnetic high which trends in an east-west direction over a ridge of Triassic conglomerate, more or less parallel to the outcrop of diabase about a half mile to the north. The diabase dips under the Triassic sediments at this location and the general distribution and configuration of the outcrop pattern suggests that the diabase is at no considerable depth beneath this anomaly location. It is noteworthy that there is no magnetic anomaly over the adjacent area of exposed diabase, suggesting that the existing anomaly is either the result of a more significant diabase mass at depth, possibly a feeder to the diabase of the area, or else is due to a ferruginous concentration in the diabase at depth. Although this magnetic anomaly exhibits a maximum intensity somewhat lower than that which occurs over the known orebodies, the proximity of high quality ore dictates further clarification of this anomaly.

From an overall examination of the magnetic pattern in the Cornwall area in the southern part of the Lebanon and Richland quadrangles, one is impressed by two features. First, there is the fact that there is a low magnetic intensity over the orebodies known to have large tonnages of magnetite ore. Secondly, there is a rather impressive line of magnetic highs which includes anomalies 1, 2, 3, 4, 5, 6 and 7; actually, an examination of the Richland aeromagnetic map will show that three more very small magnetic highs fall along the line just to the east of Figure 2 of this publication. This line of anomalies includes only two (anomalies 3 and 5, Figure 2) which are over known orebodies. Is it possible that this line of anomalies represents a feeder system controlled by a buried structure along which masses of ore and perhaps diabase were emplaced? This is a situation which would appear to merit careful exploration and reconsideration, all the more so because of the existence of known ore along part of the trend.

MANHEIM QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 256

The southern 4/5 of the Manheim quadrangle aeromagnetic map has a simple pattern with practically no variation in magnetic intensity. It is an area of Ordovician shales and limestones which are overlapped by Triassic shales and sandstones to the north. Although the Paleozoic sediments have been involved in folding, the structure is nevertheless relatively simple.

In the northern portions of the quadrangle a curved belt of positive magnetic anomalies outlines the exposure of an irregular Triassic diabase sheet. The anomalies develop their maxima, about 250 gammas in amplitude, along the contacts of the diabase where contact metamorphism of the slightly ferruginous Triassic sediments has resulted in some finely disseminated magnetite. Neither the magnetic data nor the geologic setting suggests any economically significant magnetic mineralization.

LITITZ QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 257

The Lititz quadrangle aeromagnetic map has an extremely simple, open magnetic pattern. Total magnetic variation in the quadrangle is 100 gammas and it would be less than that were it not for the existence of a diabase sheet in the northwestern corner of the quadrangle. Most of the quadrangle is underlain by lower Paleozoic limestone and shale. In the northern third of the area a wedge of north-dipping Triassic sandstones and shales overlaps the lower Paleozoic sediments. The magnetic map reflects the relatively simple structure of the area. No economically significant mineralization is indicated by the magnetic data.

COLUMBIA EAST QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 258

The Columbia East quadrangle aeromagnetic map has a very simple, open pattern except in the southwest corner of the area. There is complex structure in this quadrangle, involving extensive folding and faulting. However, in most of the quadrangle the lower Paleozoic limestones, dolomites, sandstones, and phyllite do not appear to have sufficient magnetic dissimilarities to record the structural variations.

In the southwest corner of the quadrangle, two elongate positive magnetic anomalies occur over the Susquehanna River. These anomalies each trend in a northeasterly direction, are less than a mile in length, and have amplitudes of about 300 gammas. There is no obvious explanation for their occurrence, although it is possible they may be related to small amounts of magnetite in the Harpers-Antietam units of the area. Since these anomalies are relatively limited in area and amplitude and are restricted to the Susquehanna River channel, they do not indicate a mineral concentration of economic significance.

LANCASTER QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 259

The Lancaster quadrangle aeromagnetic map exhibits very little magnetic variation. The one distinctive positive magnetic anomaly in the northwest part of the city of Lancaster is an industrial plant. Other than that, the magnetic range is less than 100 gammas in the entire quadrangle.

This is an area underlain chiefly by limestones and dolomites, with lesser amounts of shale. Considerable faulting and folding are involved in the area, but the sediments have such similar magnetic properties that the structures are not indicated by the magnetic data, nor is there any magnetic indication of mineralization in the area.

INFORMATION CIRCULAR 42. GEOLOGIC INTERPRETATION OF CERTAIN AEROMAGNETIC MAPS OF BUCKS, MONTGOMERY, AND LEHIGH COUNTIES

COLLEGEVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 210

The Collegeville aeromagnetic map exhibits a simple contour pattern with a range of no more than 150 gammas throughout the quadrangle. This is an area underlain by Triassic shales and sandstones of the Brunswick, Lockatong, and Stockton Formations; these sediments dip uniformly north-northwest and apparently have uniform magnetic intensities. No significant mineralization or variation in structure is indicated.

BEDMINSTER QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 260

The Bedminster aeromagnetic map exhibits a simple magnetic contour pattern with a total relief of only 250 gammas in the entire quadrangle. This is an area almost entirely underlain by Triassic Brunswick and Lockatong sandstones and shales of essentially uniform magnetic intensity; the edges of gently dipping intrusive diabase sheets in the northeast and northwest corners of the quadrangle contribute 150 gammas to the very moderate magnetic relief of the quadrangle. No significant mineral or structural variation is indicated.

LUMBERVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 261

The Lumberville aeromagnetic map has only a few, widely spaced contour lines; the total magnetic relief in the quadrangle is 250 gammas. Were it not for a small area of intrusive Triassic diabase in the very northwest corner of the quadrangle, the magnetic relief would only be about 100 gammas. This area has a thick sequence of Lockatong, Brunswick, and Stockton sandstones and shales which dip uniformly to the northwest. No mineralization or significant structural features are indicated by the magnetic data.

TELFORD QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 262

The Telford aeromagnetic map has an extremely simple magnetic contour pattern with only a 200-gamma range in the quadrangle. The area consists primarily of interbedded Lockatong and Brunswick shales and sandstones of Triassic age and exhibits uniform magnetic intensity; in the northwest corner of the quadrangle the edge of a gently dipping, intrusive Triassic diabase mass accounts for most of the existing magnetic relief of the quadrangle. The east-west-trending Chalfont Fault cuts through the center of the quadrangle, but there is no manifestation of it on the aeromagnetic pattern, nor is there any indication of other structural variations or mineralization.

DOYLESTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 263

The Doylestown aeromagnetic map shows a simple magnetic contour pattern with only 140 gammas of relief in the entire quadrangle. The area consists of Triassic Brunswick, Lockatong, and Stockton shales and sandstones of essentially uniform magnetic intensity. The swing in the trend of the magnetic contours to an east-west trend in the southern half of the quadrangle tends to reflect variations along an east-west fault which has been mapped in the area. No mineralization is indicated by the magnetic pattern.

LANSDALE QUADRANGLE

U.S. Geological Survey Aeromagnetic Map G.P. 264

The Lansdale aeromagnetic map exhibits a magnetic relief of 200 gammas, most of which is due to a minor anomaly in the southeast corner of the quadrangle. The map covers an area underlain by Triassic sandstones and shales of the Brunswick, Lockatong, and Stockton Formations which dip uniformly to the northwest. The southern part of the quadrangle is near the thin southern edge of the Triassic wedge of sediments and the magnetic anomaly in the southeast corner probably is due to a minor variation in the mineralogy of the Lower Paleozoic or Precambrian rocks under the Triassic sediments. No significant mineralization or structural variation is indicated in this quadrangle.

AMBLER QUADRANGLE

U.S. Geological Survey Aeromagnetic Map G.P. 265

The Ambler aeromagnetic map shows a northeast-trending magnetic low over the town of Spring House and a northeast-trending magnetic high over Fort Washington. Neither of these anomalies is an intense feature, each varying about 250 gammas from the regional norm. While both of these anomalies occur over northwest-dipping Triassic Lockatong and Stockton sediments, these areas are near the southern thin edge of the Triassic wedge of sediments. Thus, the anomaly sources are undoubtedly in the underlying Precambrian and Lower Paleozoic rocks. This conforms with the situation which was found in the Hatboro and Langhorne quadrangles, where anomalies in the older rocks can be observed to continue across the Triassic contact and under the Triassic sediments. Consideration of the small magnetic amplitude and the depth of burial of the pre-Triassic rocks suggests the anomaly is the result of minor variations in mineral composition. No significant mineralization or structural variation is indicated.

INFORMATION CIRCULAR 44. GEOLOGIC INTERPRETATION OF THE AEROMAGNETIC MAP OF ALBURTIS QUADRANGLE, LEHIGH AND BERKS COUNTIES

ALBURTIS QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 266

The aeromagnetic survey covers only the southeastern half of the Alburtis quadrangle. Considerable variation in the magnetic pattern over the area reflects the variety of lithologies and structures present. The most pronounced magnetic relief occurs in the southeastern corner of the quadrangle where Precambrian crystalline rocks are exposed or are only thinly veneered by Paleozoic sediments. In the remainder of the area, where the Paleozoic sediments are thick and of fairly uniform magnetic susceptibility, the magnetic pattern is simple and open.

The majority of the magnetic anomalies occur in the southeastern corner of the quadrangle. Here the underlying rocks are part of the northern edge of the Reading Prong, a belt of Precambrian crystalline rocks which is predominantly granitic but locally contains dark, basic units. A mile south of Emmaus, along the eastern edge of the quadrangle, there is a magnetic high with an amplitude of over 700 gammas. This is the western end of an anomaly whose peak is a mile to the east in the adjacent Allentown quadrangle. This is a significant anomaly; it is attributed to the magnetite-bearing gneiss which at one time was mined at Vera Cruz Station. Over 300,000 tons of ore, averaging 42 percent iron, is reported to have been mined there from three iron-rich zones, each up to 15 feet thick. The history and geology of the mines is well described by Miller and others (1949); the interpretation of the aeromagnetic data is discussed by Socolow (p. 18). The intensity and extent of the Vera Cruz anomaly indicate a large iron concentration whose economic possibilities merit further consideration.

Several magnetic highs occur within a mile southwest of Emmaus. Along the south edge of the quadrangle, near South Mountain, a magnetic high exhibits an amplitude of over 500 gammas. This magnetic feature lies over a narrow exposure of hornblende gneiss which contains some disseminated magnetite. A magnetic high on the northern flank of South Mountain (Upper Milford Township) is directly related to a mass of granite gneiss with a minor amount of disseminated magnetite. The same rock unit extends under the limestone at Macungie and is responsible for the magnetic high there. No mineralization of economic significance is indicated at these anomalies between Emmaus and Macungie.

Between Alburtis and Macungie there is an elongate magnetic high which extends into the East Greenville quadrangle to the south. This anomaly has an amplitude of about 300 gammas and trends northeast parallel to the gneissic structure of the area. The anomaly appears to be related to a structural knob of magnetite-bearing granite gneiss which projects up through a veneer of Hardyston quartzite. There is no indication either from the anomaly or from the rock exposures that iron concentration is adequate for economic development.

Except for a few industrial magnetic anomalies, as at Cementon and Ormrod, the remainder of the quadrangle exhibits a simple magnetic pattern of widely spaced magnetic contours with a northeast trend which reflects the general strike of the lower Paleozoic limestones, dolomites, and shales. The broad, very low intensity magnetic high at East Texas in Lower Macungie Township indicates a deep-seated feature, probably a structural high in the basement rocks which lies under a thick section of the Allentown Formation. No economic concentrations of iron ore are indicated.

INFORMATION CIRCULAR 45. GEOLOGIC INTERPRETATION OF THE AEROMAGNETIC MAPS OF HUMMELSTOWN, PALMYRA, AND BERNVILLE QUADRANGLES

HUMMELSTOWN QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 267

The aeromagnetic survey covers only the southern half of the Hummelstown quadrangle. The magnetic map shows only a very few, widely spaced contours. This area is underlain by a thick sequence of Cambrian and Ordovician limestones and shales which have low and relatively uniform magnetic susceptibilities. Except for an anomaly due to the factory at Hershey, the magnetic variation shown on the map of this quadrangle is less than 100 gammas. The magnetic pattern shows no structural trends nor any sign of significant iron mineralization.

PALMYRA QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 268

The Palmyra magnetic map shows little magnetic relief, except in the southeastern corner of the quadrangle. Most of the quadrangle is underlain by a thick sequence of northeasterly striking Cambrian and Ordovician limestones and shales which have low, uniform magnetic intensities. The only anomaly in the area of these sediments is about two miles west of Annville, and is due to the steel structure in an industrial plant. The southeastern corner of the quadrangle includes a small portion of the Triassic belt of Pennsylvania. Here the red shales and sandstones have been intruded by Triassic diabase masses which produce some magnetic anomalies.

An arcuate belt of magnetic highs may be observed in the southeastern corner of the quadrangle. These highs tend to be developed along the irregular upper contact of the southerly and southeasterly dipping diabase sheets which intruded the Triassic conglomerates, sandstones, and shales; the anomalies each have an amplitude of about 350 gammas. The anomalies are centered over the upper contact of the diabase because (1) the direction of dip causes a greater mass effect of the diabase at that position and (2) thermal metamorphism at the upper contact has partially recrystallized some of the ferruginous material in the sandstones and shales to form disseminated magnetite. Neither the amplitude of the anomalies nor the geologic setting offers any indication of iron concentrations of economic significance.

BERNVILLE QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 273

The Bernville aeromagnetic map exhibits only a few, widely spaced contour lines with less than 100 gammas magnetic relief in the entire quadrangle. The quadrangle is almost entirely underlain by a thick sequence of the highly deformed Martinsburg Formation. In the southeastern corner of the area, a small amount of the Ontelaunee dolomite is exposed. These rock units have low, uniform magnetic intensities. The magnetic pattern does not show any distinctive structural features nor any indication of ferruginous mineralization.

INFORMATION CIRCULAR 46. GEOLOGIC INTERPRETATION OF THE AEROMAGNETIC MAPS OF SOUTHERN YORK COUNTY

REGIONAL SETTING

The area of the seven quadrangles discussed here lies within the Piedmont and Triassic provinces of southeastern Pennsylvania and is commonly referred to as the York-Hanover district. It encompasses a large variety of rock types including igneous, sedimentary, and metamorphic units which range in age from Triassic to late Precambrian (Figure 3). The structures are complex and include thrust faulting, normal faulting, isoclinal folding and recumbent folding. Recent research (Freedman, pers. commun.) indicates that more than one period of folding may be involved.

This is an area of rolling topography with a relief of about 200 feet. It is extensively farmed and less than a quarter of the region is wooded. The soil cover is thin and, although outcrops are not overly abundant, the rock float within the soil offers a fairly reliable basis for geological mapping.

The aeromagnetic map patterns demonstrate the northeasterly strike of the various formations, even though only a few of the rock units appear to be highlighted by the magnetic data. Many of the complex structures, which have been mapped in the field on the basis of rock types, are not indicated on the magnetic map because of a lack of variation of magnetic susceptibility among most of the rock units. On the other hand, many minor structures, heretofore unrecognized, are indicated by the magnetic patterns established by those few rock units which are of higher magnetic susceptibility.

The southeastern half of the York-Hanover region is underlain by the metamorphic Wissahickon and Marburg Formations; the latter has been defined and separated from the Wissahickon only west of the Susquehanna River, but may be equivalent to the albite-chlorite zone of the Wissahickon in eastern Pennsylvania. The northwestern half of the area is mainly underlain by the slightly less metamorphosed Harpers, Antietam, Chickies, and Conestoga Formations. On older geologic maps the northwestern and southeastern halves of the region covered by this publication are separated by the "Martic thrust." The aeromagnetic maps show that the two halves have essentially similar magnetic expressions. The existence of the "Martic thrust" has not been demonstrated in York County.

Certain impure quartzitic units in the Marburg Formation are so similar in magnetic pattern to those of the Chickies-Harpers-Antietam sequence that they suggest a possible correlation of those units. These quartzites occur as thin members and discontinuous lenses within the larger schistose units. Varying amounts of ferruginous material may be observed along the strike of the quartzites. The iron occurs as hematite and disseminated magnetite; it is the latter which is responsible for the many magnetic highs which are developed at certain localities over the quartzitic units. Some of these ferruginous zones contain nearly 40 percent iron, sufficiently rich to merit consideration for development of iron ore production; this is particularly true where the magnetite content is considerably augmented by hematite. Although the presence of significant magnetite in the quartzites is indicated by the intensities of the magnetic anomalies, the total available iron content is commonly unrelated to the magnetic intensity, due to the presence of the nonmagnetic hematite. In several localities of high iron content, hematite is more prevalent than magnetite. The magnetic anomalies themselves, therefore, can serve as a guide to the ferruginous zones, but the real potential of these zones can only be established by evaluation in the field.

Microscopic examination of the impure iron-bearing quartzitic beds in the Chickies and Harpers Formations shows that this sedimentary material technically should be called graywacke. Intensive alteration and recrystallization have occurred, resulting in textural and mineralogical changes. Disseminated euhedral magnetite grains were formed early in the metamorphic process, followed by the development of specular hematite, muscovite, recrystallization of the clastic quartz grains, and chloritization at the expense of muscovite and iron-magnesium silicates. The quartz grains exhibit complete interlocking intergrowth as a result of the recrystallization; some larger quartz grains developed elongation parallel to schistosity as a result of the recrystallization. The schistosity of the sericite and specularite bends around the euhedral magnetite grains and there is a preferential development of secondary quartz and muscovite in the plane of schistosity around the earlier magnetite crystals. Megascopic and microscopic evidence suggests that the magnetite and specular hematite result from recrystallization of original hematite in the graywacke. Variation of the magnetite-hematite content in the present schistose graywacke (impure quartzitic) members is probably related to variation in the original iron content in the sediments.

In the southeastern portion of the York-Hanover region a large number of magnetic highs over the Wissahickon Formation appear to be related to the interlayered metabasalts (Stose and Jonas, 1939, p. 85) within the formation and to certain members in the schist, other than quartzitic ones, which are somewhat higher in iron content. The metabasalts contain a considerable quantity of iron silicate minerals, notably epidote and chlorite, as well as varying amounts of disseminated magnetite. The magnetite is at least partially the result of alteration and mobilization during the time of regional metamorphism. The somewhat iron-rich zones in the schist itself contain small amounts of disseminated magnetite as well as some chlorite and biotite. This mineralogy is variable along strike and probably downdip as well, for in a few instances the surface mineralogy is difficult to reconcile with the recorded anomaly. Field examinations and sample analyses of the Wissahickon material indicate a low available iron content with little or no likelihood for

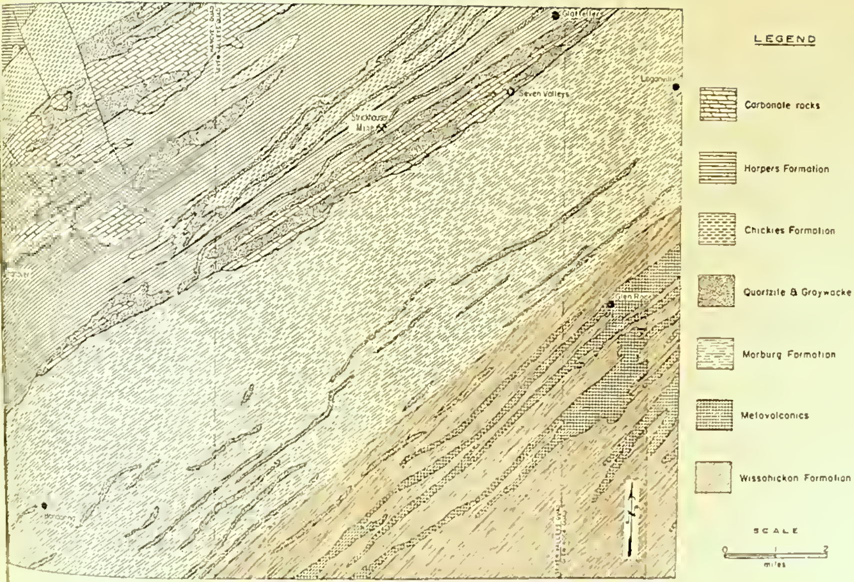

Figure 3. Geology of the York-Hanover district.

economic iron concentrations. This is in marked contrast to the very real economic potential of the hematite- and magnetite-bearing beds in the Chickies and Harpers Formations as mentioned above.

YORK AND RED LION QUADRANGLES

U. S. Geological Survey Aeromagnetic Maps G. P. 270 and G. P. 271

The York and Red Lion quadrangles encompass a large number of lithologic units but exhibit a fairly simple pattern on the magnetic maps with relatively few magnetic anomalies. Cutting across the quadrangle are belts of Wissahickon and Marburg schist, Harpers Formation, Antietam Formation, Conestoga limestone, and a sequence of Cambrian dolomites. The northeasterly strike predominates, but the structure is complex. The more outstanding magnetic anomalies are associated with quartzitic members in the Chickies and Harpers Formations.

About two miles north of Dallastown, in the York quadrangle, there is a prominent magnetic high which trends northeasterly and extends onto the adjacent Red Lion quadrangle where it reaches its maximum intensity near the village of Holtz. This anomaly has an amplitude of about 500 gammas, a width of about half a mile, and a total strike length of approximately five miles (including the portion in both quadrangles). The source of the anomaly is an impure quartzitic bed in the Chickies Formation which can be readily traced in the field by the wooded ridge which it supports; it extends for at least five miles and has an average width of about 400 feet. Extensive float material along the ridge and several road cuts through it offer good opportunities for sampling. The material consists of impure quartzites with texture ranging from granular and sandy to schistose. It is composed chiefly of quartz grains with varying amounts of muscovite and chlorite. Disseminated through the rock are small crystals of magnetite, the major source material of the anomaly, and occasional pseudomorphs of limonite after pyrite crystals. Weathering of the magnetite and pyrite has resulted in considerable limonite stain. No significant hematite is present. The country rock is cut by many irregular veins of milky quartz which was apparently mobilized during a late stage of the regional metamorphism.

In considering the economic potential, the available iron content in this particular locality would be based on the amount of magnetite present. Although there are local lenses in the quartzitic material which may run as high as 15 percent recoverable iron, the average grade does not run much more than 5 percent iron. It appears, thus, that this anomaly zone offers no possibility for economic development as an iron producer.

A half mile north of the village of Holtz in the Red Lion quadrangle there is a magnetic high geologically related to the Holtz anomaly described above, although more restricted in areal extent. This anomaly results from a repetition by folding and faulting of the magnetite-bearing quartzitic member of the Chickies Formation which is responsible for the anomaly at Holtz. Here too, although the anomaly has an amplitude of nearly 500 gammas, the limited magnetite content precludes the possibility of an economic iron ore development.

A distinct positive magnetic anomaly occurs about one mile east of Yorkana in the Red Lion quadrangle. This magnetic high has an amplitude of 260 gammas and involves an area nearly a mile in diameter. It is centered over the contact of Harpers phyllite and Chickies slate. Field examination reveals no outcrop, but muscovite schist predominates in the soil cover, as well as a considerable amount of quartzitic material. A small amount of limonitic staining may be observed, but there is no iron mineralization observable which adequately explains the origin of the anomaly. It is possible that the magnetic high is due to a relatively local concentration of disseminated magnetite which can be observed elsewhere in the region as lenses of limited extent. The size and amplitude of the anomaly offer no encouragement for an economically significant iron concentration here.

A small magnetic high occurs in Lower Windsor Township, 2½ miles northeast of Windsor, in the Red Lion quadrangle. This anomaly, less than a half mile in diameter with an amplitude of 200 gammas, is developed over slates and phyllites within the Marburg Formation. Field examination reveals no outcrop, but the float consists of phyllite containing limonite pseudomorphs after pyrite crystals. There is no apparent source of the magnetic anomaly, but a local concentration of disseminated magnetite is very possible. Neither the field geology nor the magnetic data suggest an iron concentration of economic proportions.

In the southeastern corner of the Red Lion quadrangle there is an elongate magnetic high developed over a quartzitic member of the Wissahickon schist. The anomaly extends onto the adjacent Safe Harbor quadrangle. The rock is quartzitic muscovite schist with some chlorite and vein quartz present. Some limonite staining is present, but no magnetite or hematite can be observed. Although the geological and geophysical data offer no encouragement for a major iron concentration, it is of academic interest to note the relationship of this anomaly to a quartzitic member.

A narrow magnetic high cuts across the southeast corner of the York quadrangle, trending northeasterly, parallel to the regional strike. This anomaly can be traced for about two miles into the Red Lion quadrangle, and for at least six miles toward Loganville in the Glen Rock quadrangle. This magnetic feature, with a maximum amplitude of about 400 gammas, is developed over Marburg schist. Field examination reveals no outcrops, but the float is muscovite schist with some milky vein quartz; no magnetite nor hematite was observed and limonitic staining is minimal. It is probable that the anomaly source is a thin, ferruginous member of the Marburg Formation which is hidden under the soil cover. The limited amplitude and width of the anomaly and the lack of field evidence, even in the soil, do not offer encouragement for the existence of economically significant iron ore.

A small magnetic high is centered in Windsor Township, about four miles east of the center of York. The anomaly has an amplitude of about 200 gammas and covers an area approximately a half mile in diameter. Another magnetic high of about 100 gammas in amplitude and linear in outline occurs to the west about halfway between York and Spry. Both of these magnetic features are developed over thin ferruginous quartzitic members. Neither the magnetic data nor the surface geology offers any indication of commercial ore grade at these two anomaly areas, but it is of interest that the Windsor Township occurrence is within the Harpers phyllite, whereas the very similar occurrence just to the west is within the Chickies slate.

The northern part of the York quadrangle is underlain mainly by Conestoga limestone and several Cambrian dolomites. The magnetic pattern is simple and indicates no distinct structural or mineralogical features.

GLEN ROCK QUADRANGLE

U. S. Geological Survey Aeromagnetic Map G. P. 272

The Glen Rock quadrangle includes two major rock units: the Marburg Formation and the Wissahickon Formation. In the Marburg Formation a prominent magnetic high is located close to Loganville; it extends into the York and Red Lion quadrangles and has been discussed in the section above dealing with those quadrangles.

The Wissahickon Formation occupies the southern two-thirds of the Glen Rock quadrangle. A large variety of rock types is contained within this formation, including schists, gneisses, quartzites, and metabasalts. As in the case of the Wissahickon in Lancaster and Chester Counties to the east, there is considerable magnetic variation over this formation in York County. Although a few of the anomalies in the Glen Rock quadrangle appear to be related to the interbedded metabasalts, this is not a general rule. The three or four most prominent anomalies are associated with schistose facies.

A prominent positive magnetic anomaly is centered over the Wissahickon schist in Springfield Township, three miles southeast of Loganville. This magnetic high has an amplitude of about 500 gammas and is nearly two miles in length and a mile in width. Field examination at this locality reveals chiefly muscovite schist and phyllite with a very minor amount of limonite stain; there are also a few stringers rich in chlorite, biotite, and hornblende as well as some milky quartz veinlets. No magnetite or hematite was observed, nor does there appear to be a quartzitic bed present, such as is the host rock for magnetite and hematite in the nearby Seven Valleys, York, and Red Lion quadrangles. The source of this magnetic high is not apparent, although a relatively shallow, iron-rich lens in the schist is possible. Despite the fact that the anomaly does not suggest a very large source of high iron content, its intensity in this general area of hematite and magnetite occurrences offers some encouragement for further exploration.

Half a mile south of Hametown, along old Route 111, there is a magnetic high of about 250-gamma amplitude which covers an area a half mile in diameter. As in the case described in the paragraph above, this magnetic feature occurs in an area of Wissahickon muscovite schist with no magnetite or hematite showing in the surficial material. A shallow, lenticular concentration of iron-bearing minerals seems to be the most likely magnetic source, although neither the magnitude nor amplitude of this anomaly offers an indication of a concentration of economic dimensions.

North of Glen Rock in the west-central section of the quadrangle, a pronounced magnetic high occurs along the northeast-trending contact of the Marburg and Wissahickon Formations. This anomaly can be traced for about four miles along Route 216 in the Glen Rock quadrangle and an additional two miles in the Seven Valleys quadrangle to the west. Field examination reveals a predominance of muscovite schist, and lesser amounts of quartzitic material and chlorite schist. Tiny, disseminated magnetite crystals account for up to 3 percent of the rock volume and are undoubtedly the source material of the magnetic anomaly. The rock is cut by milky quartz stringers, probably mobilized during regional metamorphism. Weathering has produced some limonitic stains on the rock material, but there is essentially no hematite to be seen in either outcrop or float. It appears, therefore, that the recoverable iron content (in the magnetite) is far too small to merit economic consideration.

A magnetic high occurs a half mile due east of Glen Rock and can be traced in a southwesterly direction for about six miles, extending into the adjacent Seven Valleys quadrangle. This magnetic anomaly, as well as another located two miles south of Glen Rock, is developed directly over metabasalts within the Wissahickon Formation and is attributable to the magnetite and iron silicate minerals present. These anomalies achieve a maximum amplitude of about 600 gammas, yet field examinations to date have not yielded any material with economically significant iron mineral content.

ABBOTTSTOWN AND WEST YORK QUADRANGLES

U. S. Geological Survey Aeromagnetic Maps G. P. 281 and G. P. 282

The Abbottstown and West York aeromagnetic maps show a very simple magnetic contour pattern with very little magnetic relief and no significant anomalies. This is not due to the absence of lithologic variety or structures, but rather to the relatively uniform degree of magnetic susceptibility of the rocks present.

The northwestern half of the area included in these two quadrangles consists of a northwesterly thickening wedge of Triassic sandstones, siltstones, and shales. The Triassic sediments are predominantly red in color and dip uniformly to the northwest.

The southeastern half of the area has many complex folds and thrusts and includes Cambrian dolomites, limestones, quartzites, and phyllites. Unlike the stratigraphic units just to the south, these various lithologic horizons show no appreciable magnetic variation even when followed out along strike into the adjacent quadrangles.

No economically significant iron concentrations are indicated in the Abbottstown and West York quadrangles.

HANOVER AND SEVEN VALLEYS QUADRANGLES

U. S. Geological Survey Aeromagnetic Maps G. P. 286 and G. P. 287

The Hanover and Seven Valleys aeromagnetic maps show a few pronounced magnetic highs which merit close attention. The lithologic variation within these quadrangles is extensive. It includes the crystalline Wissahickon, Marburg, Antietam, and Harpers Formations, as well as numerous Cambrian and Ordovician limestones and dolomites. There is intense folding and faulting of the predominantly carbonate sequence in the northwesterly portion of these two quadrangles, but the magnetic pattern is devoid of any significant anomalies there.

It is in the central and southern parts of the area that two belts of strong anomalies over the northeasterly striking crystalline rocks indicate that extensive exploration is in order.

A prominent belt of magnetic highs can be traced southwesterly from Glatfelters, in the northeast corner of the Seven Valleys quadrangle, to

Wildasin Chapel in the south-central section of the Hanover quadrangle, a length of about 12 miles. The anomaly is complex, having numerous peaks and many branches or digitations. The geologic map (Stose and Jonas, 1939), as well as current detailed field examination, shows that this complex belt of anomalies is related to magnetite-bearing quartzitic beds in the Chickies and Harpers Formations. The impure quartzitic units can be traced across the countryside on the basis of topography. Due to strong erosional resistance, they are ridge formers as compared with the adjacent schist and phyllite. There are numerous outcrops, particularly where the roads cut through the ridges; float is also quite plentiful. The rock is composed of quartz, muscovite, disseminated magnetite crystals and some chlorite. It is a metasedimentary unit, originally a very impure sandstone or a graywacke, which has undergone considerable recrystallization and has developed some schistosity. Under the microscope the quartz grains show an angular, interlocking pattern which was probably produced during regional metamorphism. Magnetite is a rather persistent component, but the distribution of the magnetite crystals varies from place to place within the quartzitic units; this undoubtedly accounts for the variation in magnetic intensity as shown on the magnetic maps.

The ferruginous quartzitic units of the Chickies and Harpers belt appear to vary in thickness from a few tens of feet to a couple of hundred feet. Due to the intense isoclinal folding involved, undoubtedly accompanied by deformational thickening and thinning, it is difficult to assess how much of the variation in thickness is primary or secondary and how much is due to structural repetition. There are zones of up to 50 percent magnetite content in the quartzitic units, particularly in the Harpers, although the average is probably more on the order of 15 or 20 percent magnetite content.

Strickhouser Specularite—Magnetite Prospect

In the Seven Valleys quadrangle, the occurrence of a dense, specular hematite zone adjacent to a relatively rich magnetite-bearing quartzitic member of the Harpers focuses attention on this belt for possible economic potential. If it can be demonstrated that the fairly thick specular hematite zone has considerable lateral extent or can be ascertained along any significant portion of the 12-mile extent of the magnetite-bearing unit, then this iron concentration would have dimensions of real economic significance. The specularite occurrence is located in North Codorus Township, a half mile north of Strickhouser and two miles west of Seven Valleys. This is the site of an old mining operation which was variously known as the Codorus, Strickhouser or York Iron Company

Mine. The mine is located in a wooded area atop a ridge supported by a quartzitic, magnetite-bearing member of the Harpers. Frazer's (1876) account indicates that this mine was opened in 1854 and was operated for over 20 years, producing more than 100,000 tons of ore. Ore analyses reported by Frazer (1876, p. 30) show an average iron content of 36.3 percent, with 36.9 percent silica, 0.22 percent phosphorous, and 0.004 percent sulfur. Mining was conducted mainly as an open pit operation, although two underground drifts, still accessible today, contributed considerable ore tonnage. Field mapping (Figure 4) shows that the mining was developed along three parallel zones of the specularite, each up to 80 feet thick. Bedding and cleavage are both very steep and it is not yet clear whether the three zones constitute individual horizons or one unit repeated by structural deformation. Numerous small drag folds suggest intense folding. It is to be noted that the material which was mined is magnetite-bearing specularite schist, while the adjacent magnetite-bearing quartzitic unit, the one responsible for the extensive magnetic anomaly, was not developed due to a relatively lean iron content.

Microscopic examination of the ore material shows up to 50 percent specular hematite, about 10 percent euhedral magnetite, 20 to 50 percent of recrystallized interlocking quartz grains, and varying amounts of muscovite and chlorite. Textural relationships show that the magnetite crystallized first, followed by the specularite, sericite, quartz, and chlorite in that sequence.

The walls of the specularite zones are defined by pale-green fissile phyllite. The vertical extent of the ore zones has not been established, either by the early mining or by more recent exploratory drilling. The mining of years ago has demonstrated a vertical extent of at least 150 feet; the open pit itself has a vertical face of over 60 feet. Lineations, believed to be bedding-cleavage intersections, have a persistent southwesterly plunge of up to 35°. In this area of intense, nearly vertical cleavage and obscure bedding, a correct structural interpretation will be a significant factor in evaluating vertical extent and the related tonnage figure.

The area of mining at this Strickhouser locality has a lateral extent of a little over 1200 feet, with a secondary pit developed in a fault- displaced segment of the magnetite-bearing quartzite a few hundred feet to the northeast. The belt of high-grade specularite ore can be traced along strike by outcrop and float for about 3,000 feet. From there on, to the northeast and to the southwest, there is no surficial evidence of continuance of the hematite, even though the magnetite-bearing quartzitic horizon persists for miles and can be readily traced on the magnetic map

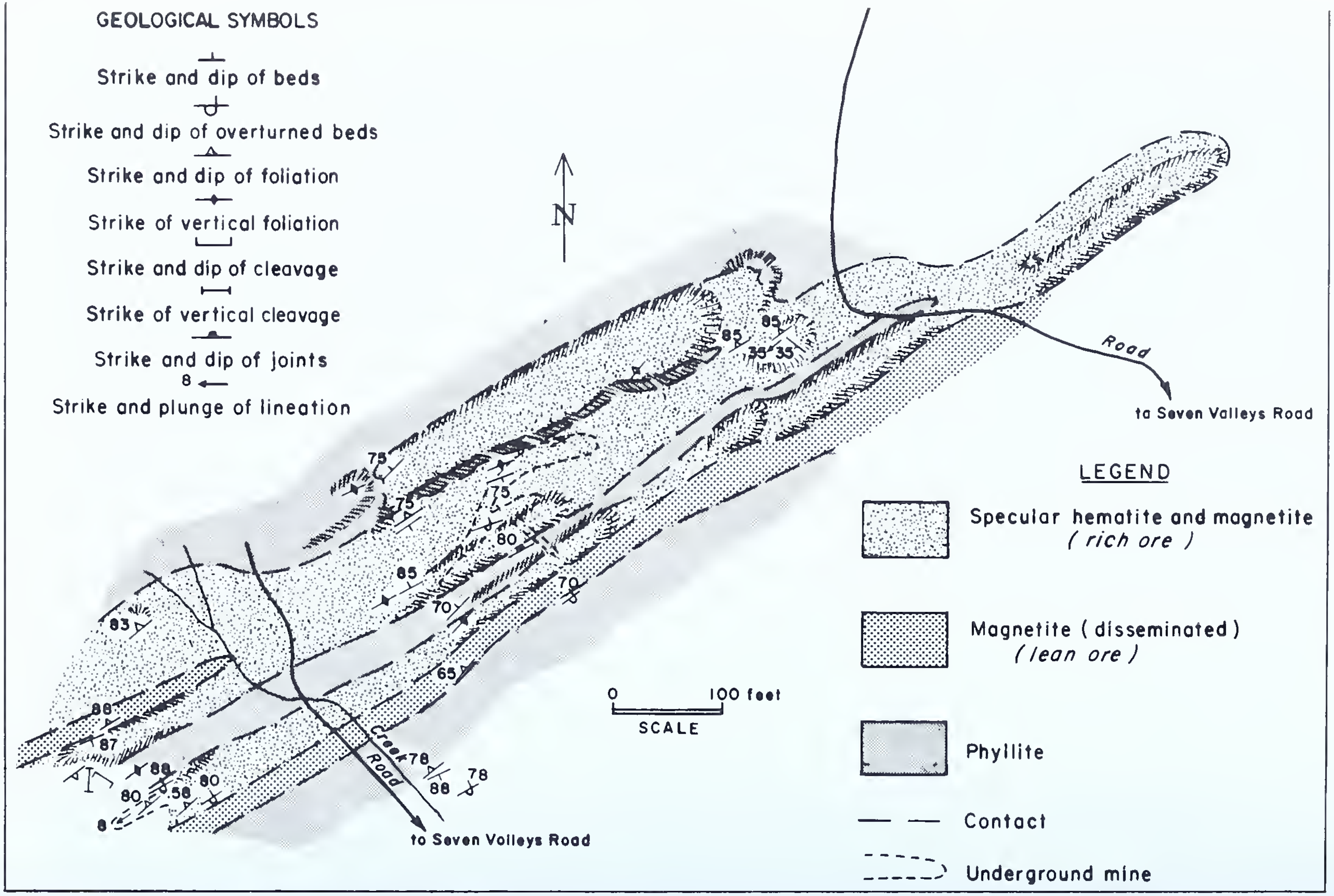
GEOLOGICAL SYMBOLS
Strike and dip of beds
Strike and dip of overturned beds
Strike and dip of foliation
Strike of vertical foliation
Strike and dip of cleavage
Strike of vertical cleavage
Strike and dip of joints
8
Strike and plunge of lineation
N
Road
to Seven Valleys Road
Creek
Road
to Seven Valleys Road
0
100 feet
SCALE
LEGEND
Specular hematite and magnetite (rich ore)
Magnetite (disseminated) (lean ore)
Phyllite
Contact
Underground mine
85
85
35
35
75
75
75
80
85
70
70
65
83
88
87
88
80
58
80
8
78
88
78

Figure 4. Preliminary geological observations at Shickhouser mine.

as well as in the field. It will require trenching or drilling to establish the ultimate limits of the specular hematite zone.

The Strickhouser specularite occurrence merits further detailed research and exploration for both academic and economic motives. Academically it would be desirable to shed more light on the nature of the source beds and the metamorphic processes responsible for the specularite and the magnetite members. It would also be desirable to establish whether or not there is actual correlation of the magnetite-bearing quartzitic units in the Harpers and Chickies Formations.

From the standpoint of economic potential, the situation at Strickhouser's is enticing. The three high-grade specularite-magnetite zones have a combined thickness of nearly 200 feet; in addition, there is the adjacent, leaner grade magnetite-bearing sandstone which might lend itself to utilization. With the better grade ore known to extend over a length of 1200 feet and an additional 1800 feet indicated, it becomes apparent that sizeable tonnages are involved.

Bandanna Magnetic Anomaly

A pronounced positive magnetic anomaly occurs over the Marburg Formation near Bandanna, six miles southeast of Hanover. The Bandanna anomaly has an amplitude of about 1,000 gammas and can be traced southwestward, parallel to the regional strike, for four miles to the Maryland border where the present magnetic survey ends. Field evidence indicates that this anomaly is related to a quartzitic member in the Wissahickon Formation, similar to the magnetite-bearing quartzitic members. In the case of the Bandanna anomaly, however, outcrops are nonexistent and there is no convincing magnetite occurrence in the limited float present. The magnitude and dimensions of the anomaly, however, suggest that a significant concentration of iron mineralization must be present at a relatively shallow depth, a few hundred feet at most. In this region of known magnetite and hematite concentrations, further exploration, probably drilling, appears warranted at the Bandanna anomaly locality.

REFERENCES

Armstrong, E. J. (1941), *Mylonitization of hybrid rocks near Philadelphia*, Geol. Soc. America Bull., v. 52, p. 667-694.

Bascom, Florence and others (1909), *Description of the Philadelphia district*, U. S. Geol. Survey Geol. Atlas, Folio 162, 23 p.

——————— (1909), *Description of the Trenton quadrangle, New Jersey and Pennsylvania,* U. S. Geol. Survey Geol. Atlas, Folio 167, 24 p.

——————— (1931), *Geology and mineral resources of the Quakertown-Doylestown district, Pennsylvania and New Jersey,* U. S. Geol. Survey Bull. 821, 62 p.

Bascom, Florence and Stose, G. W. (1932), *Description of the Coatesville and West Chester quadrangles,* U. S. Geol. Survey Geol. Atlas, Folio 223, 15 p.

——————— (1938), *Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania,* U. S. Geol. Survey Bull. 891, 145 p.

Bayley, W. S. (1941), *Pre-Cambrian geology and mineral resources of the Delaware Water Gap and Easton quadrangles, New Jersey and Pennsylvania,* U. S. Geol. Survey Bull. 920, 98 p.

Bromery, R. W. and others (1959a), *Aeromagnetic map of the Allentown quadrangle, Northampton, Lehigh and Bucks Counties, Pennsylvania,* U. S. Geol. Survey Geophys. Inv. Map GP-213.

——————— (1959b), *Aeromagnetic map of the East Greenville quadrangle, Berks, Lehigh and Montgomery Counties, Pennsylvania,* U. S. Geol. Survey Geophys. Inv. Map GP-205.

Buckwalter, T. V. (1959), *Geology of the Precambrian rocks and Hardyston Formation of the Boyertown quadrangle,* Pa. Geol. Survey, 4th ser., Atlas 197, 15 p.

Cloos, Ernst and Hietanen, A. M. (1941), *Geology of the "Martic overthrust" and the Glenarm Series in Pennsylvania and Maryland,* Geol. Soc. America Spec. Paper 35, 207 p.

d'Invilliers, E. V. (1883), *The geology of the South Mountain belt of Berks County,* Pa. Geol. Survey, 2nd ser., Rept. D3, v. 2, 441 p.

Frazer, Percifor, Jr. (1876), *Iron ore belts in York and Adams Counties,* Pa. Geol. Survey, 2nd ser., Rept. C, 198 p.

Geyer, A. R. and others (1958), *Geology of the Lebanon quadrangle,* Pa. Geol. Survey, 4th ser., Atlas 167c.

Gray, Carlyle (1952), *The high calcium limestones of the Annville belt in Berks and Lebanon Counties, Pennsylvania,* Pa. Geol. Survey, 4th ser., Prog. Rept. 140, 17 p.

Gray, Carlyle, Geyer, A. R. and McLaughlin, D. B. (1958), *Geology of the Richland quadrangle, Pennsylvania,* Pa. Geol. Survey, 4th ser., Atlas 167d.

Gray, Carlyle and Lapham, D. M. (1961), *Guide to the geology of Cornwall, Pennsylvania,* Pa. Geol. Survey, 4th ser., Gen. Geology Rept. 35, 18 p.

Hawkes, H. E., Jr., Wedow, Helmuth, Jr. and Balsley, J. R., Jr. (1953), *Geologic investigation of the Boyertown magnetite deposits in Pennsylvania,* U. S. Geol. Survey Bull. 995-D, p. iii, 135-149.

Hickok, W. O. (1933), *The iron ore deposits at Cornwall, Pennsylvania,* Econ. Geology, v. 28, p. 193-255.

——————— (1939), *Iron ores of Pennsylvania,* Pa. Geol. Survey, 4th ser., Min. Resource Rept. 18b, 21 p.

Jonas, A. I. and Stose, G. W. (1926), *Geology and mineral resources of the New Holland quadrangle, Pennsylvania,* Pa. Geol. Survey, 4th ser., Atlas 178, 40 p.

——————— (1930), *Geology and mineral resources of the Lancaster quadrangle, Pennsylvania,* Pa. Geol. Survey, 4th ser., Atlas 168, 106 p.

Knopf, E. B. and Jonas, A. I. (1929), *Geology of the McCalls Ferry-Quarryville district, Pennsylvania,* U. S. Geol. Survey Bull. 799, 156 p.

Lesley, J. P. (1883), *The geology of Lehigh and Northampton Counties,* Pa. Geol. Survey, 2nd ser., Rept. D3, Pt. 1, p. i-xxiv, 1-82.

Miller, B. L. (1925), *Allentown quadrangle—mineral resources,* Pa. Geol. Survey, 4th ser., Atlas 206, 195 p.

Miller, B. L., Fraser, D. M. and Miller, R. L. (1939), *Northampton County, Pennsylvania,* Pa. Geol. Survey, 4th ser., County Rept. 48, 496 p.

Miller, B. L. and others (1941), *Lehigh County Pennsylvania,* Pa. Geol. Survey, 4th ser., County Rept. 39, 492 p.

Smith, L. L. (1931), *Magnetite deposits of French Creek, Pennsylvania,* Pa. Geol. Survey, 4th ser., Min. Resource Rept. 14, 52 p.

Spencer, A. C. (1908), *Magnetite deposits of the Cornwall type in Pennsylvania,* U. S. Geol. Survey Bull. 359, 102 p.

Stose, A. J. and Stose, G. W. (1944), *Geology of the Hanover-York district, Pennsylvania,* U. S. Geol. Survey Prof. Paper 204, 84 p.

Stose, G. W. and Jonas, A. I. (1939). *Geology and mineral resources of York County, Pennsylvania,* Pa. Geol. Survey, 4th ser., County Rept. 67, 199 p.

Willard, Bradford and others (1959), *Geology and mineral resources of Bucks County, Pennsylvania,* Pa. Geol. Survey, 4th ser., County Rept. 9, 243 p.

GRAPHIC ARTS INTERNATIONAL UNION LABEL
GAU
LOCAL UNION